Training programme on

Capacity Building for Rural Energy Development Activities

New Delhi, April 7 to 10, 1997

sponsored by

Action for Food Production (AFPRO), New Delhi

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Training Programme - Schedule

Days	Duration	Session	Contents
Day 1 (7.3.97)	0.9.30–9.45	Inauguration	Introduction to training programme and its objectives
	9.45–10.30	Rural energy scenario	Present national and regional rural energy scenario
	10.30–11.00	Tea/coffee break	
	11.00–12.00	Overview of government programmes & Policy issues	• Government programmes • Policy issues
	12.00–13.00	Overview of RETs	• Biomass technologies
	13.00–14.00	Lunch	
	14.00–15.30	Overview of RETs	• Solar thermal • Solar photovoltaic • Wind energy • Small hydro power
	15.30–16.00	Tea break	
	16.00–16.30	Overview of Rural energy planning	
	16.30–17.30	Audio visual session	• Video films on RETs
Day 2 (8.3.97)	9.30–11.00	Rural energy planning	• Energy planning methodologies
	11.00–11.30	Tea	

	11.30–13.00	Survey techniques	• Interviews • Questionnaire design • Sampling • PRA
	13.00–14.00	Lunch	
	14.00–15.30	Classroom session-I	• Group discussion
	15.30–16.00	Coffee/tea break	
	16.00–17.30	Classroom session-II	• Case study discussion
Day 3 (9.3.97)	8.30–17.30	Field exercise	• Village survey • Technology demonstration
Day 4 (10.3.97)	9.30–11.00	Presentation-I	• Presentation on field visit
	11.00–11.30	Coffee/tea break	
	11.30–13.00	Presentation-II	• Group discussion • Presentation
	13.00–14.00	Lunch	
	14.00–15.00	Concluding session	• Question-answer • Synthesis and feedback
	15.00	Coffee/tea break	

Session I

Rural Energy — An Overview

The session presents an overview of the rural energy scenario in the country and in context of the present energy consumption patterns and the supply and expected demand for energy sources.

Contents

- Rural energy demand and supply
- Environmental aspects of rural energy use
- Issues in rural energy policy

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Rural energy scenario in India

Introduction

India is the second most populous nation in the world, endowed with a rich ecological diversity[1]. Seventy per cent of its population (over 650 million) is rural, and meeting its energy requirements in a sustainable manner continues to be a major challenge for the country. Traditional biomass resources still meet an overwhelming proportion of the rural energy demand. One of the main reasons of this continued dependence on biomass is the failure of the commercial fuels such as kerosene and LPG to penetrate the rural areas on account of high costs and low accessibility. On the other hand, inefficient use of biomass in traditional devices has serious environmental effects at the local level. In the past two decades, there have been several attempts by way of promoting various renewable energy programmes, forestry programmes, etc. but their impact has been significant enough neither to make a dent on the growing energy demand in the rural areas nor to mitigate the adverse environmental effects. Notwithstanding, with the rural population poised to cross 750 million by the turn of the century, the energy requirements would be enormous and there is a need to develop innovative approaches to deal with the rural energy problems in the future.

Energy consumption patterns

In the rural economy, domestic household sector is the most prominent energy consumer, followed by the agricultural sector. The industrial sector (including commercial establishments) is not very significant in the rural areas as far as energy consumption is concerned, though rural industries like brick kilns are energy-intensive and use fuelwood extensively. The share of the rural transportation sector is marginal with dependence on traditional modes of transport. Energy use patterns in different rural sectors are briefly discussed here.

Domestic sector

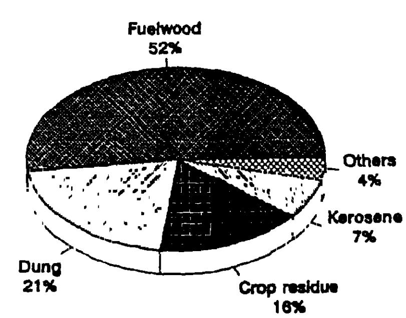
The household sector is the major energy consumer accounting for nearly 75% of the energy used. Cooking is the largest end-use contributing to almost 90% of the household energy with the rest taken up by lighting and heating. Biomass fuels -- fuelwood, crop

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[1]According to classification made by the Planning Commission of India, the country is divided into 15 different agroclimatic zones representing diverse characteristics.

residues and animal residues -- provide 85-90% of the domestic energy and 75% of all rural energy. Among the other fuels, only kerosene is dominant being used mostly for lighting. Given the geographical diversity in the country, the consumption pattern varies considerably across different states and districts. The per capita consumption of fuelwood, for instance, ranges from 0.14 kg per day in Haryana to 1.31 kg per day in forest-rich Himachal Pradesh. The fuel-mix also varies from region to region depending on the resource endowments. Fuelwood consumption is high in states (for instance, all the North-eastern states) where there is considerable forest over, whereas dungcakes play an important role in states like Bihar (0.72 kg), Punjab (0.50 kg) and Haryana (0.70 kg) which have little biomass cover. Crop residue, being inferior in quality, is used in most areas as a backup fuel when other fuels are in shortage, such as West Bengal (0.43 kg) and Punjab (0.32 kg).

Energy consumption in domestic sector



Source: NCAER 1985

Agricultural sector

In the agricultural sector, animate energy (human and draught power) accounts for more than one-third of the total energy consumed. The other direct energy inputs are mainly in irrigation through diesel and electrical pumpsets, and diesel consumption for tractors used in tilling, harvesting, etc. Irrigation is the most important end-use, and there are about 10 million electric and 6 million diesel pumpsets in the country.

Industry and commercial sector

While small industries and commercial establishments (hotels, restaurants, shops, etc.) in rural areas as well as urban areas consume significant quantities of fuelwood, no authentic statistics are available on the extent of consumption. Most of these establishments are in the informal sector and hence lack no proper records, and also the fuelwood sources are very diffused.

The following table provides a summary of information available on different industries.

Table 1. Fuel consumption by different industries

Industry	Specific wood consumption	Fuelwood consumed per annum
Bakeries	0.7 kg/kg of output	Not available
Rubbersheet making	1 kg/kg of fresh latex	Not available
Vanaspati ghee	0.67 kg/kg ghee	630,000 tonnes
Fabric printing	0 2 kg/meter of cloth	1,720,000 tonnes
Soap	250-300 kg/400-500 bars	Not available
Charcoal	4 kg/kg of charcoal	Not available
Tobacco curing	4-10 kg/kg of cured leaf	440,000 tonnes
Tea drying	1 kg/kg of dry tea	250,000 tonnes
Cardamom curing	Not available	75,000 tonnes
Brick	8-10 kg/100 bricks	Not available
Silk cocoon	17-25 kg/kg of silkyarn	100,000 tonnes
Lime making	0.34 kg/kg of limestone	Not available

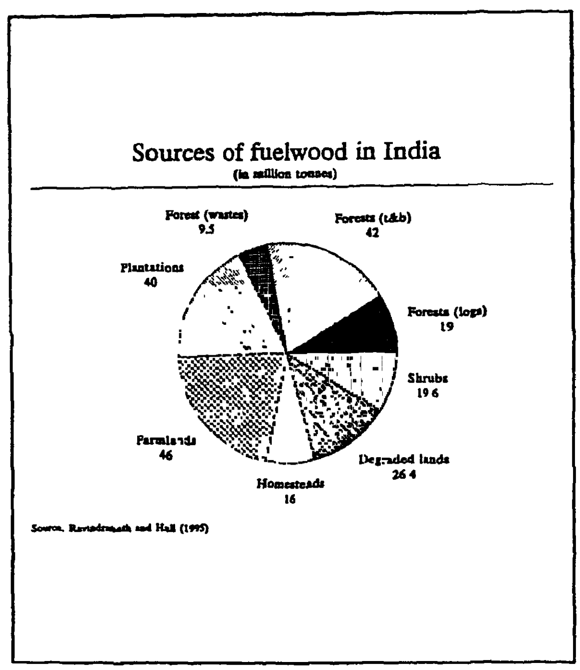
Rural energy supply and demand

Fuelwood

The present level of consumption of fuelwood is around 200 million tonnes per annum. However, this is only an average figure with estimates ranging between 100 and 300 million tonnes[2]. The per capita or per family consumption of fuelwood varies considerably across different regions and agro-climatic zones depending on the resource endowments and accessibility. Also, most of the fuelwood consumed in the rural areas is collected in the form of twigs and branches, mainly by women and children, and not purchased.

[2]One of the major problems in studying the rural energy systems is the lack of an authentic method to assess the supply and demand of energy. The variance in different estimates is quite high, depending on the set of assumptions made.

On the supply side, it is estimated that the annual sustainable yield[3] from different land sources is about 86 million tonnes -- 36 million tonnes from forests and the rest from other lands such as plantations, revenue lands, wastelands, etc.[4]. Thus there is a wide gap between the demand and the sustainable supply, and this gap is widely believed to be met from illicit and unsustainable exploitation of biomass resources. The following figure shows the different land categories and their contribution of fuelwood. Forests contribute just about 32% of the total fuelwood while the rest comes from a variety of other sources.



Given the trend, the demand for fuelwood by the turn of the century is expected to cross 300 million tonnes. At the present rate of supply, this will clearly result in further degradation of the biomass resource base, and containing this demand would be a major concern.

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[3]The biomass that can be harvested annually without adversely affecting the regeneration capacity of the land source.

[4]The latest estimates of the Forest Survey of India put the annual incremental yield from the forest lands at only 30 million tonnes.

Animal residues

Animal waste in the form of dungcakes is an important fuel in the regions which are agriculturally prosperous but where the fuelwood supply is poor. The total current consumption of dung as fuel is about 100 million tonnes per annum. On the other hand, the total supply is about 200 million tonnes[5]. However, most of the dung produced is used as manure in the fields, and diversion of its use for fuel has a large opportunity cost[6]. Also given the fact that the cattle population has not grown significantly in the last two decades, the availability of dung for fuel use is likely to increase only marginally in the future.

Crop residues

Crop residue is the least preferred of the biomass fuels because, being in loose form, the rate of combustion is high and difficult to control. As a consequence, it is also an inefficient fuel. However, this acts as a back-up fuel wherever there are scarcities of fuelwood, and is gaining prominence as the fuelwood availability is becoming difficult. It is estimated that about 100 million tonnes of non-fodder crop residue is produced and consumed as fuel in different parts of the country.

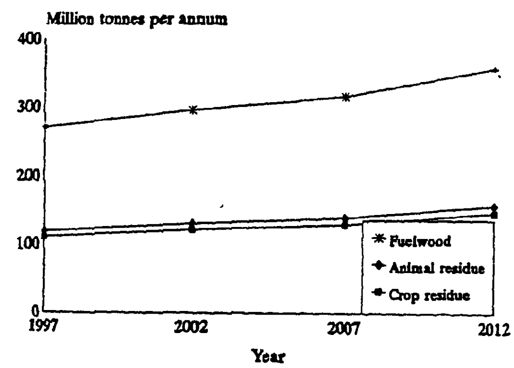
The following figure shows the estimates of demand for different biomass fuels during the next two decades. Clearly, fuelwood would remain the most important fuel in the rural energy sector.

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[5]There are nearly 300 million bovine animals in India which produce about 1000 million tonnes of wet dung which gives 200 million tonnes of dung on a dry basis.

[6]It is estimated that the fertilizer value of the dung used as fuel would be about Rs 2500 crores (US$ 800 million) per annum. Fresh dung contains 2% nitrogen, and the current price of urea is Rs 250 per quintal.

Biomass fuel demand



Source: TERI (1995)

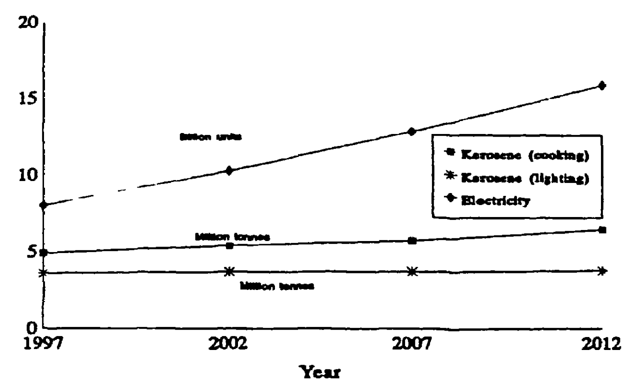
Commercial fuels

Kerosene and electricity are the other important fuels in the domestic sector, while diesel and electricity are prominent in agriculture. Presently about 8 million tonnes of kerosene and 6 billion units of electricity are consumed in the rural areas, and the demand is expected to go up to 9 million tonnes and 10 billion units respectively, by year 2002. Also, kerosene use for cooking will grow faster than kerosene for lighting which is expected to be taken care of by electricity, as shown in the following figure[7].

[7]As mentioned, kerosene is supplied through the Public Distribution System (a network of fair price shops) of the government. Given the highly decentralised nature of PDS, there are several administrative loopholes (pilferage, diversion for other uses, etc.) in its operation (for instance, in several states, a part of the kerosene is illegally routed for use as transport fuel in combination with petrol). There is an obvious need to strengthen PDS.

Even then, it is unlikely that commercial fuels can be increased in supply significantly because of competing demands in other sectors like industry and transport. Given the large import bill India pays for petroleum products, rural sector is unlikely to be given preference.

Commercial fuel demand in rural domestic sector



Source: TERI (1995)

In the agricultural sector electricity demand is expected to grow sharply in the next two decades along with diesel, assuming that large-scale mechanisation would take place.

Impact of rural energy on society and environment

As is evident, the energy demand, especially that of biomass fuels is going to increase substantially which could only increase the gap between the demand and the sustainable supply. This would have a deteriorating effect on the resource endowment apart from other manifestations which are briefly discussed here.

Impact on natural resource base

It is an established fact that forests and other public lands in India, given the pressures of high population growth rate, are in various stages of degradation severely affecting their carrying capacity[8]. One of the major casualties of this situation is fuelwood which is becoming scarce in several parts of the country. Though no direct correlation between deforestation and rural energy use has been established -- demand for agricultural land, and industrial and commercial requirements are considered the principal causes[9] -- there is

[8]It is estimated that there are presently 50 to 70 million hectares of wastelands in the country. Nevertheless, these lands continue to be put under productive use due acute population pressure.

[9]Between 1952 and 1980, a total of 4.33 million hectares of forest was cleared of which 60% was for cultivation.

evidence that where the land is already degraded, fuelwood extraction could exacerbate the process. With domestic households as well as rural industries using increasing quantities of fuelwood, this situation could only worsen in the future.

Monetisation of biomass

This is another dimension to the problem of natural resource degradation. Apart from the rural consumption, a significant part of the urban population both in small towns and large cities use fuelwood, and markets exist to cater to these. The main source of these markets is the fuelwood brought on headloads from the villages surrounding the town. Headloading is a regular profession in many parts of the country, especially where agriculture is erratic or seasonal. As this trade becomes a regular source of livelihood for people in these villages, the tendency would be to exploit the biomass resources unsustainably, and even illegally, which has an adverse impact on the resource base. It is estimated that 2 to 3 million rural people are engaged in headloading as a regular profession.

Impact on quality of life

As mentioned earlier, fuel collection in rural areas is mostly done by women, except in some cases of headloading, which puts a heavy burden on them. This is particularly so in the hilly areas where women also have to participate in all the other productive activities. As fuelwood becomes scarce, women are forced to spend more time and walk long distances to collect fuelwood. This extra burden affects the quality of life substantially as it cuts into the time and attention women could pay to their children's education and health, and other household activities. Several micro level studies conducted in different ecological settings, indicate that distances up to 10 km are covered in the process expending 5 to 6 hours per day.

Pollution due to biomass burning is a major factor that affects the quality of life in a major way. Burning of biomass in inefficient cookstoves is one of the major causes of chest and lung related health problems among rural women and children[10]. This problem would be particularly severe in a scarcity situation where households may be forced to switch to inferior fuels such as fuelwood from shrubs, roots and weeds, and crop residue in loose form.

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[10]A WHO estimate estimates that over 650,000 children die of Acute Respiratory Infections (ARI) a significant fraction of which could be correlated to biomass pollution.

Global impacts

Biomass energy consumption, apart from local environmental effects, also has serious impact on climate change due to emissions of greenhouse gases. The process of degradation and depletion of forests -- which results in loss of natural sinks that could absorb carbon emissions -- and biomass burning, have been identified as significant contributing factors to the greenhouse effect. In India it is estimated that of the 68.3 million tonnes of carbon released annually, fuelwood use accounts for 82.3%. Thus, it is important to take this potential contribution into account in the issue of sustainable biomass use.

Financial allocations for renewable energy sector

One of the main reasons -- apart from other reasons such as high initial costs, shortcomings in implementation methods, limited number of mature technologies, etc. -- for low penetration of renewable energy technologies has been the low level of investment made by the government in the sector. For instance, between 1981 and 1992, the government expenditure on grid electricity was Rs 812 billion; Rs 335 billion on petroleum; and Rs 158.5 billion on coal. Compared to this, the investment in renewable energy was a meager Rs 11.55 billion. This low priority was reflected in the VIII Five Year Plan (1992-97) allocation, too, with renewable energy having a share of just 0.8%..

Of the VIII Plan allocation of Rs 8.57 billion for the renewables, almost 50% would be spent on biogas and improved chulha programmes, a major part of which would be in the form of direct subsidies. However, the budget allocation for these programmes in the last two years has not increased in real terms as attempts are being made to rationalise the subsidy patterns, and to involve local entrepreneurs in the implementation process.

Institutional aspects of rural energy

The main feature of the institutional structure in the rural energy sector is the multiplicity of organisations involved in different programmes at various levels. There are several ministries and apex bodies formulating policies and monitoring the progress of individual programmes. Also, the Planning Commission is involved in these exercises in order to allocate annual budgets for specific programmes. However, there is little role or no coordination among the various agencies to ensure proper programme planning. Then there are nodal agencies at the state level which implement the programmes through district

level bodies (eg District Rural Development Agency) and block level bodies (eg. Block Development Office). In addition, there are a host of non-governmental organisations, research/academic institutions, etc. who are involved in the programmes in various capacities. However, there is very little for the lower level bodies in the policy formulation.

The state level nodal agencies (and in some cases, the state departments) are responsible for the implementation of various programmes. For most of the programmes, the finances are provided by the central government with the state governments taking care of the establishment costs[11]. In that sense, state nodal agencies are dependent on the Centre for their existence[12].

A 'top-down' approach is adopted in the implementation of programmes. The physical targets are set at the central level which are then transmitted to various levels below, and often these targets are determined independent of actual requirements. The lower level bodies are supposed to send quarterly progress reports to the respective higher agencies, but there is no effective mechanism is in place that this reporting is regular and the feedback is acted upon. The rural people, the ultimate beneficiaries of the programmes, have little role in deciding the design and content of any rural energy programme. In fact, several evaluation studies point out that target-orientation as one of the major causes for the programme failures.

Role of international funding

Multilateral agencies like the World Bank, and bilateral agencies like country aid missions have had an intermittent presence in the rural energy sector for a long time. The international support was extended to governmental as well as non-governmental organisations. Initially, in the 70s and mid-80s, the emphasis had been on afforestation programmes which led to support of social forestry projects by the World Bank, Ford

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[1]Apart from the funds provided for subsidies, training, awareness creation, technical back-up, etc. for pecific programmes (NPBD, NPIC, IREP, Urjagram), MNES also pays service charges to the nodal agencies epending on the targets. For instance, if the yearly target for biogas plants is over 20,000, the nodal agency eceives Rs 2.15 million plus Rs 50 per every plant in excess.

The new government that took over at the centre in June 1996 announced that the central schemes nplemented in the states in the rural development sector might be transferred to the states with appropriate nancial allocations. However, this needs to be planned systematically to understand the implications of such policy.

Foundation, Swedish International Development Agency (SIDA), Canadian International Development Agency (CIDA), Norwegian Development Agency (NORAD), etc. However, none of these projects had providing energy as one of the primary objectives. But there have been other projects which have had direct relevance to rural energy. Some of them are discussed below:

The Canadian Hunger Foundation (CHF) supported a large biogas programme implemented through a network of 68 NGOs all over the country. This project was coordinated by the Action for Food Production (AFPRO), based in New Delhi. These NGOs were part of NPBD in that they avail the subsidies of the government, and the CHF funding was utilised in maintenance of personnel, training programmes, post-installation services, etc. Of 10 years duration, this project ended in 1995.

UNDP provided US$ 1.5 million in 1987 to the Ministry of Non-conventional Energy Sources to set up Solar Energy Centre, which is envisaged to conduct R&D in solar energy to develop the technology indigenously. Another US$ 2.9 million was also given for development of Amorphous Silicon Solar Cells in India to promote photovoltaic technology.

DANIDA also extended assistance through UNDP-GEF to the tune of US$ 7.5 million to exploit the small hydro resources in the Himalayan region. This project envisages setting up 20 pilot small hydro power projects in the 13 Himalayan states of India, and coming up with a comprehensive action plan for developing the small hydro resources in the region. One of the sub-objectives of this 42-month project, being executed by MNES, is to substitute fuelwood with electricity in the hilly areas.

The Swiss Development Cooperation (SDC) is assisting efforts to promote energy efficiency in rural industries such as brickmaking, glassware, silk processing, etc. The silkreeling project in Karnataka and Andhra Pradesh, of 5 years duration, is aiming to propagate biomass gasifiers for reeling operations. Energy conservation projects in brick and glassware industries are in Uttar Pradesh.

Recently, the Rockefeller Foundation has given assistance to create 100 energy self-sufficient villages based on biogas electricity in Karnataka. GEF has lent support to SUTRA project (Sustainable Transformation of Rural Areas), to be implemented by the Indian Institute of Science, Bangalore, which would aim at sustainable use of biomass resources for providing energy. Currently, US$ 196,000 was sanctioned for a pilot project and to prepare a large implementation project.

The US Department of Energy launched a US$ 3 million project in 1995 for promoting commercialisation of renewable energy technologies in India.

Currently, the World Bank is playing a prominent role in promoting the commercialisation of renewable energy technologies through the *India Alternate Energy Project*.

These are only a few illustrations of international assistance. While the overall impact of such assistance is limited in the context of rural energy sector, international organisations will continue to have an important role to play in future, too, given the constrained resource situation in the country. Also, such funding would enable flexibility in attempting new approaches and methods.

Session II

Government Programmes — An Overview

This session describes various rural and renewable energy programmes that the Government of India has implemented/ initiated in the country, either through the Ministry of Non-conventional Energy Sources (MNES) or through other agencies. The aim is to familiarize the participants with these programmes and the impacts that these have had on the rural energy scenario.

Contents

- National Programme on Improved Cookstoves (NPIC)
- National Project on Biogas Development (NPBD)
- Rural electrification
- Integrated Rural Energy Planning (IREP) programme
- *Urjagrams*

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National Programme on Improved Chulha (NPIC)

Introduction

The improved cookstove program was launched as a demonstration program in 1983. The driving force behind this attempt was to conserve fuelwood and protect forests. In April 1985, it was converted into a full fledged program called The National Program on Improved Chulhas (NPIC).

Objectives of NPIC

- Fuel conservation.
- Removal/reduction of smoke from the kitchen.
- Check on deforestation and environmental upgradation.
- Reduction in drudgery of women and children from cooking in smoky kitchens and collection of fuel.
- Reduction in health hazards.
- Reduction in cooking time.
- Employment opportunity to the rural poor.

Program structure

Institutional arrangement

NPIC is implemented by the State Governments and Union Territory Administration, State Nodal Agencies and corporate bodies like State Agro Industries Corporation. Rural artisans, potters, blacksmiths etc. have also been made a part of the programme.

Agencies involved in NPIC

- State Government Departments.
- Non conventional Energy Development Agencies.
- State Agro Industries Development Corporations.
- Khadi Village and Industries Commission.
- National Dairy Development Board.
- Women Organizations (AIWC, SEWA, etc.).
- Other NGOs.

The list of nodal departments implementing agencies is given in Annexure.

A network of 16 Technical Back up Units (TBUs) has been created under NPIC for providing technical and training inputs in addition to R & D support to the state governments and nodal agencies. The major thrust areas for R & D in chulhas are development of high efficient metal-clad-ceramic lined chulhas and reduction in unit cost through innovative design and alternative materials.

Functions of TBUs

- R & D including development of appropriate models according to local needs;
- Training to self employed workers, potters, village artisans, and various field level functionaries;
- Demonstration: adoption of villages for demonstration and field trials of various technologies developed; and
- Decentralized testing and approval of models.

Technical back up units have been authorised to grant approval to portable metallic chulhas. ISI marked chulhas have also been introduced under the National Programme to ensure quality control, durability and longer life. Eight TBUs have been recognised by the Bureau of Indian Standards (BIS) as Test Centres for ISI marked chulhas. The TBUs could be approached for availing assistance on technical design and manufacture of new and improved models as well as for testing of new models.

The list of TBUs is given in the Annexure.

Training programmes

Training programmes are organised through the TBUs and the implementing agencies for self employed workers, potters, entrepreneurs, technicians and field functionaries. Management/exposure training programmes are also organised for the officers of the agencies at various levels for proper and effective implementation. For the first time, a training programme for entrepreneurs was organized in 1995–96 with the objective of training potters and artisans in the manufacturing and marketing of pottery lined chulhas.

Financial arrangement

The pattern of financial incentives given under the program have been summarized in Box I.

Box I. Financial incentives under NPIC

For end user

Central subsidy

- Fixed = Rs 50 (max.) subject to a minimum contribution of 50% of the cost of chulha by beneficiary
- In plains: Portable = 33% of cost, max. Rs 50 (General) & 50% of cost, maximum Rs 75 (SC/ST). In hills: 50% of cost maximum Rs 75 (all beneficiaries)
- High altitude: metallic chulha 50% of cost maximum Rs 250 per chulha

For self employed workers

- Incentives of Rs 20 per fixed chulha, Rs 5 per portable chulha & Rs 25 per community chulha

For state nodal and other implementing agencies

- User's education and publicity incentive (Rs 2 per chulha)
- Incentive for TBUs (where state has not made provision) (Rs 2 per chulha)
- Incentive for organizational support (Rs 4 per chulha)
- Training programs and refresher courses for SEWs, state and district level officers, NGOs, users etc.

For cooperative stores & fair price shops

- Incentive of Rs 5 per portable chulha to increase sale outlets in rural areas

The government has announced 100% depreciation under the Income Tax Act in respect of renewable energy devices including improved chulhas. No industrial licensing is required under the provisions of the Industries (Development and Regulation Act) for manufacturing improved chulha. A substantial reduction in the custom duty has been made by the government for the import of machinery/components required (if any) for the manufacture of improved chulhas. There is 100% exemption of central excise and general sales tax/central sales tax for improved chulhas. Indian Renewable Energy Development Agency Ltd. (IREDA) provides soft term loans (5 to 13 ½%) to the manufacturers of improved chulhas.

Evaluation and feedback

Regular inspections and evaluation studies on functionality of installed chulhas is carried out by state nodal departments, implementing agencies, TBUs and regional offices of MNES.

Types of improved chulhas

The programme envisages installation of fixed and portable metallic chulhas. Fixed models of chulhas are being installed by trained self employed workers. The minimum thermal efficiency for improved chulhas has been fixed at 20 and 25 per cent for fixed and portable chulhas, respectively, as against the thermal efficiency of 5 to 10 per cent of traditional chulhas. Model of improved chulhas with thermal efficiency up to 40% have recently been developed which are under field trials.

The following options are available for selection of models under the National Programme:

(a) Mud fixed chulhas with or without chimney.
(b) Mud-clad pottery lined fixed chulha with or without chimney.
(c) Portable metallic chulha.
(d) Portable metal-clad-ceramic lined chulha.
(e) Portable chulha with separate hood and chimney system.

Damperless fixed chulha and metallic portable chulha are available with different power ratings, capability of using different fuels and cooking one or more dishes simultaneously. Improved chulha for community, commercial and industrial applications have also been developed. There are a number of approved models in fixed and portable categories for family, community and commercial applications.

Performance of the program

About 195 lakh improved chulhas had been installed in the country by the end of March, 1995. The coverage of ICs programme has reached 18.51% of the estimated potential of 1200 lakh chulhas. The share of fixed type chulhas is 70% and that of portable chulha is 30 per cent. An evaluation of NPIC carried out by the National Council for Applied Economic Research (NCAER) reported an average functional rate of 60.3% of the chulhas installed between 1988–91. Subsequently, another evaluation study done by NCAER found a functional rate of 86.2% for ICs installed during 1991–92. Some important observations are:

(a) functionality rate of chulhas is improving every year;
(b) success rate of old chulhas is low as these have finite life;

(c) nearly 20% of non working chulhas can be put back by repair and maintenance;

(d) the fixed and portable chulhas are 1.4 and 1.5 times more efficient, respectively than the traditional chulhas; and

(e) the stove use level declines with age.

Strategy for large scale extension

(a) Association of beneficiaries in selection of models.

(b) Modification of the designs appropriate to users needs.

(c) Greater participation of users.

(d) More thrust on users' education.

(e) Introduction of incentive schemes for various levels of field functionaries, depending upon functional percentage.

(f) Wider publicity through Radio, TV and other modes.

(g) Easy availability of various models of chulhas.

(h) Liberalised marketing:

- Decentralised registration of models;
- ISI marked portable metallic chulhas introduced for better quality, durability and longer life; and
- Involvement of PDS, FPS etc. for sale of portable chulhas.

Review of the programme

Review of the envisaged benefits of the technology

A review of the IC program can be best done by evaluating the program in terms of extent of fulfillment of its major objectives viz. fuelwood savings, removal or reduction of smoke, reduction in cooking time, and employment generation.

Fuelwood savings

Fuel saving is perceived as a benefit of using improved chulhas by a majority of users. Ninety per cent owners of working chulhas reported savings in monthly fuel consumption in the national survey of 1993 conducted by NCAER. Field experiments on improved chulhas have also shown considerable savings. Some important observations made in this reard are:

- A high incidence of IC acceptability is found in regions where fuel is scarce or where fuel is generally purchased.
- Fuel savings decreases with increase in the age of the improved chulha.

Time saving

Reduction in cooking time is substantially achieved by the use of improved cookstoves however further research work is needed to look at this benefit more closely

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Cooking time is relatively decreased when using improved chulhas. In an all India opinion survey carried out by NCAER in 1993, only 18% users expressed their dissatisfaction over the large time taken by ICs for cooking. Field measurements have also shown a reduction of 40% in the cooking time.

Removal/reduction of smoke

Some of the major reasons for IC adoption are smoke removal, improved health and cleaner kitchen. The non users too appreciate the smoke removal ability of ICs

Removal or reduction of smoke in the kitchen has also been achieved to a large extent. Reduction in the incidence of eye and lung diseases and advantage of smoke elimination as a major benefit is perceived by over 35% of the chulha owners in the country as per the national survey conducted by NCAER.

Employment generation

It has been estimated that a work force of 25 million people at all levels, is existing under NPIC.

Reasons for non adoption of cookstoves

Reasons reported by various studies for non adoption of ICs include:

Incompatibility of the cookstove design with cooking habits

These include small feeding chamber and unsuitable pot hole size. Since the replacement cost of the materials is very high compared to the benefit of the chulha (if adopted), the non users are not in favor of switching over to improved chulhas.

Structural defects

Such as defective quality of pipe, improper chimney sealing, corrosion/breakage of liners, blockage of flue etc.

Cost

The cost of improved chulhas vary depending on the cooksotve design. For example, the cost of the ASTRA stove is Rs 150 and households are expected to finance the installation and claim a part of the cost later as subsidy. A poor household would have to spend the wage earnings of one week (at Rs 20/day). Thus, the first cost of a stove is still high and acts as a deterrent to adoption, especially for the poor. The possibility of providing loans is yet to be explored.

Fuel gathered at no cash cost

Majority of rural households gather fuelwood, while dung cakes and crop residues are available as by-products with no cash expenditure, although their preparation usually involves significant human effort. Thus, there is little financial incentive to invest in an improved stove.

Other reasons

Such as existing fuel not suitable, occupies large space, possible fire hazards etc.

Usage rate

Though the dissemination rates of improved cookstoves are quite impressive however, follow up surveys indicate a very low usage rate. In a survey conducted by TERI in 26 villages (292 households)in four blocks of Jodhpur district, only 10 improved chulhas could be located in the villages though the improved chulha program had been in force in the area for a long time. Further, out of these ten chulhas only two were in use at the time of the survey. The rest had been abandoned because of problems relating to improper construction or had not been installed at all.

Acceptance of Improved cookstove

Elimination of smoke is an equal or more important consideration than conserving biomass in using improved stoves. A housewife is likely to use the improved stove as long as it provides one or more benefits such as savings in fuel, cooking time, and removal of smoke, and does not cause problem. Nationally, 60 per cent of improved stoves in use are providing some benefit assuming that discontinued use of all stoves is due to stove failure or to stove-related problems. Some of the reasons for dismantling of the improved stove

are: moving the kitchen, shifting to a new house, repairs to the house, splitting of joint families, the stove having been built in the wrong location, switching to biogas plants, etc. The structural and operational problems arise due to inadequate training of builders or lack of communication with the housewife before and after construction of the stove. She often does not know what to expect from a stove or how to use and maintain it.

Review of the programme

As regards to the program itself, the draw backs have been repeatedly identified by a number of evaluation studies. The program seems to have benefitted the richer rural households more with the proportion of working chulhas increasing with the increase in income of the households.

Drawbacks

- Inappropriate stove design.
- Low field efficiency.
- Target specific dissemination.
- Absence of quality control.
- Lack of user education.
- Inadequate trained builders.
- Low funds.
- Shortage of staff.
- Lack of appropriate user training.

Centralized macro approach

Centralized macro level approach based on target completion has further lend to the program a degree of inefficiency and unreliability. This approach has also resulted in the non consideration of the local traditions and customs of communities in program implementation. In the socio economic impact assessment of the Urjagram project in village Achanakmar, Madhya Pradesh carried out by TERI; one of the reasons for the non use of fixed improved chulhas was that the tribals of the village shifted their residence in the event of a death in the family, thus abandoning the chulhas along with the houses.

Inadequate funding

Currently about 2 million stoves are built per year. If a subsidy and expenditure of Rs 50/stove is assumed, then currently the ministry is spending Rs 160 million /year. This accounts for about 7 per cent of the total budget for all renewable energy sources. If the programme was to be stepped up to an annual target of, say, 20 million stoves, the allocation would have to increase commensurately. Therefore, unless funding from MNES is greatly increased, there is no possibility of significantly enhancing the targets. The mode

of dissemination has to be changed to encourage self-employed workers to promote high-performance stoves.

Disappropriate allocation of funds
In terms of budgetary allocation, the economic value of the program is marginal compared to other rural based programs such as, poverty alleviation or irrigation. Further, in proportion to the funds allocated to NPIC, the work that has to be put in by the BDO and his staff is more. The BDO selects the villages, finalizes the list of beneficiaries, collects the beneficiary's share of the chulha price, arranges to purchase and transport all accessories like cast-iron grate, and chimney pipe finds a suitably trained worker to install chulhas, pays the worker on installation etc. The total money involved in this work ranges from Rs 30,000 to Rs 50,000 which is negligible in comparison to funds allotted to other developmental activities like construction of roads, schools, community centers etc. Also, the funds received from the center are mechanically distributed to the implementing agencies.

Poor performance
The performance of the improved stoves is poor in many locations and thus may not motivate householders. Quality control is absent in the programme.

Absence of service facilities
Currently at the village level, there are no trained persons available for repair. This makes households even more hesitant to spend money on a facility for which maintenance is a problem.

Lack of information on stoves
In many villages, the households are unaware of the improved stove design. Even if they know about its existence they may not know about its potential benefits, the cost, whom to contact, or the availability of a subsidy.

Shortage of staff
In the villages, the program is implemented by the *zila parishad* through *panchayat samities*. The task of motivation, selection of beneficiaries etc. lies with the *Gram Sewak*. Shortage of staff at the level of the *panchayat samities* and presence of a single *Gram Sewak* to cater to a number of villages results in negligence.

Inaccessibility of the technology

The number of trained builders is very small and there is only one master trainer per district (of about 1500 villages) in states like Karnataka. The master trainer is expected to perform several functions, such as certifying the stoves, keeping records of the programme, and attending meetings, apart from training builders. To contact a builder the village has to go to the district headquarters. Furthermore, the components of the stove. such as chimney, grate, and primary vent door, are not available in the village. Thus, even if a family is prepared to pay the full cost of the improved stove, it is not readily accessible.

Insensitivity to gender roles

Reflecting on the implementation of the program, it visibly lacks the sensitivity to the issue which that is seen primarily as a 'women's problem'. Elaborating further. women's labor is perceived as free and hence of no economic valve. This socio-cultural attitude contributes heavily to giving the NPIC a lower status in the eyes of the men who take the monetary decisions.

Non demonstrative execution

Though NPIC is conceived as a demonstration program, it is executed without any effort to identify areas within the block where chulhas can be installed so as to provide an effective demonstration center. Consequently, the impact of the program has been 'scattered'.

Unrealistic expectations

An important reason for the unsatisfactory performance of NPIC has been the unrealistic expectations held at the beginning regarding fuel saving, with the presumption that huge efficiency gains were easy to attain which would make improved chulhas irresistible to users.

However, with time these expectations have changed significantly. An important reason for this change is the growing realization that cookstoves do not function with the same efficiency in field in comparison to the controlled conditions of the laboratory. There is a general agreement amongst the professionals that an average of 50 per cent reduction in fuel consumption should be considered a major achievement and that stove programs should be content with savings of 25 percent or even less.

Imbalance of perceived and real benefits

Another wrong assumption made at the inception of NPIC was that a more efficient stove is superior to a traditional stove. Traditional stoves have numerous other benefits such as

space heating, protection from insects (smoke), accommodation of different pot sizes and ability to use different fuels as per the season. These benefits though lower the efficiency but, make TCs more acceptable in comparison to the improved versions. Thus, improved efficiency cannot be the sole aim of any program. What the cookstove program lacks is it's inability to strike an appropriate balance between the perceived benefits and the real social benefits governed by the nature of stove and the cooking practices of the users.

Potential

A potential of 120 million improved chulhas has been estimated for the country covering the rural and semi urban households. Assuming a stove dissemination rate of 2 million/year, another 53 years would be required to provide stoves to all the remaining households. Further, a majority of stoves built are mud stoves which have a life of around 5-8 years, if properly maintained. Thus the stoves installed also will have to be replaced, and at the current rate of provision, all rural households may never obtain an improved stove. The magnitude of the program is thus beyond comprehension. If one were to replace 13 crore chulhas, it would require the present budgetary allocation for the improved chulha program to be increased to hundred fold. The point that the implementing agencies do not seem to realize is that it is impossible to replace all traditional chulhas with efficient improved cookstoves on the basis of the current rate of dissemination and subsidized program.

LIST OF TECHNICAL BACK UP UNITS (TBUs) :

S. No.	Name of TBU
1.	Chief Project Co-ordinator, Central Fuel Research Institute, P.O. FRI, Dhanbad-828108. (Shri.P.K. Bandyopadhyay)
2.	Scientist-in-Charge, Central Glass & Ceramic Research Institute, Khurja (U.P.)-203 131. (Shri. T.K.Dhan)
3.	Department of Mechanical Engineering, Regional Engineering College, Warrangal (A.P.) - 506004 (Prof. T.L.Sitharama Rao)
4.	Head, Energy, Assam Science, Technology and Environment Council, Panchawati, Silpukhuri, Guwahati. (Shri. P.C. Sarma)
5.	Technical Backup Unit, Home Management Department, Faculty of Home Science, M.S.University, Baroda. [Dr. (Mrs.) Rachel George]
6.	Hony. Director, Energy Research Centre, Punjab University, Chandigarh-160 014. (Prof. S.K.Sharma)
7.	Associate Professor (Agri. Engg.), Dr. Yashwant Singh Parmar University, Nouni, Solan (H.P.) - 173 230. (Dr. O.P.Sharma)
8.	K.G.Polytechnic, Gogji Bagh, Srinagar, Kashmir - 190 001. (Shri. S.S. Rufai)
9.	Executive Secretary, Karnataka State Council for Science and Technology, Indian Institute of Science, Bangalore-560 012. (Dr. A.N.N.Murthy)
10.	Assistant Professor Mechanical Engineering, College of Engineering, Thiruvananthapuram,Kerala, PIN - 695016 (Sh. M.R. Sarath Chandra Das)
11.	Prof. & Head, Centre of Energy Studies and Research, School ofEnergy Studies, Devi Ahilya Viswa Vidyalaya, Khandwa Road Campus, Indore - 452 001. (Dr. R.L. Sawhney)
12.	Director, CASTFORD, C/0 Indian Institute of Education, 128/2, Karve Road, Kothrud, Pune - 411 029. (Dr.A.D.Karve)
13.	Scientist, Design & Project Engineering Group, Regional Research Laboratory, Bhubaneshwar-751013 (Dr. S.Khuntia)
14.	Principal & Project Director, Thapar Polytechnic, Patiala - 147 001. (Dr. O.P.Single)
15.	Principal Scientific Officer, College of Technology & Agri. Eng. Rajasthan Agricultural University Udaipur - 313 001. (Prof. A.N.Mathur)
16.	Professor & Head, Dept. of Bio-Energy, College of Agricultural Engg., Tamil Nadu Agricultural Unv., Coimbatore - 641 003. (Prof. M.Ramanathan)
17.	Professor of Chemistry University of Kalyani, Kalyani, District-Nadia, West Bengal - 741 235. (Prof. C.P.Dutta)

LIST OF NODAL DEPARTMENTS IMPLEMENTING AGENCIES :

For further details, please contact your nearest block/district office. At the state HQS, there are nodal department and agencies to look after the Improved chulha programme, as under :

1. Managing Director, Non-conventional Energy Development Corporation of Andhra Pradesh Limited, (NEDCAP) 5-8-207/2 Pisagh Complex, Nampally, Hyderabad 500001.
2. Secretary, Rural Development Department, Government of Assam, Dispur.
3. Director, Bihar Renewable Energy Development Agency (BREDA), Shikarpur House, Dr T.N. Banerjee Marg, Chajjubagh, Patna-800001
4. Development Commissioner, Panchayat and Rural Housing Department, Government of Gujarat, Block No. B, Sardar Bhavan, Sachivalaya, Gandhinagar-382010.
5. Director, Gujarat Energy Develoment Agency (GEDA) Suraj Plaza II, 2nd Floor, Sayajiganj, Vadodara - 390005
6. Managing Director, Gujarat Agro Industries Corporation Limited, Energy Division, 3rd Floor, Bhavani Chambers, Ashram Road, Ahmedabad 380009.
7. Commissioner and Secretary, Social welfare Department, Government of Haryana, New Secretariat, Chandigarh.
8. Secretary, Rural Development Department, Nigam Vihar, Government of Himachal Pradesh, Shimla -171002.
9. Chief Executive Officer, HIMURJA, Chandi Bhavan, Chotta Shimla, Shimla-171002.
10. Managing Director, H.P. Agro Industries Corporation Limited, Saligram Bhavan, Shimla - 171002.
11. Chief Executive, J&K Renewable Energy Development Agency, Department of Science and Technology, Government of Jammu and Kashmir, Civil Secretariat, Jammu Srinagar.
12. Secretary, Rural Development and Panchayat Raj Department, M.S. Building, 3rd Floor, 3rd Stage, Bangalore.
13. Director, Agency for Non Conventional Energy and Rural Technology, (ANERT) P.B. No 1094, Kesavadasapuram, Pattom P.O., Thiruvanathapuram-695004
14. Managing, Director, Madhya Pradesh, Urja Vikas Nigam, B-Block, GTB Complex,T.T. Nagar, Bhopal.
15. Secretary, Rural Development Department, Government of Maharashtra, Mantralaya, Bombay-400032
16. Director, Maharashtra Energy Development Agency, (MEDA) S.No. 191/A, Phase-I, II Floor, MHADA Commercial Complex, Opp. Tridal Nagar, Yerawada, Pune-411006
17. Secretary, Rural Development Department, Government of Mizoram, Aizawl.
18. Secretary, Science and Technology, Government of Manipur, Imphal.
19. Secreatry, Planning Department, Government of Meghalaya, Shillong.
20. Commissioner and Secretary, Science and Technology Department, Government of Nagaland, Kohima.
21. Chairman, Orissa, Renewable Energy Development Agency, S-59, Mancheswar Industrial Estate, Bhubaneswar - 751010.
22. Project Director and Secretary, Tourism and Local Administration, District Rural Development Agency, 75, Jawaharlal Nehru Street, Pondicherry - 605001.
23. Secretary, Rural Development Department, Government of Punjab, Chandigarh.
24. Chief Executive Officer, Punjab Energy Development Agency (PEDA), S.C.O. No. 54-56, Sector 17-A, Chandigarh - 160017.
25. Secretary, Rural Development and Panchayati Raj Department, Government of Rajasthan, Jaipur.
26. Secretary, Rural Development Department,Government of Sikkim, Thashiling Secretariat, Gangtok.
27. Commissioner-cum-Secretary, Department of Rural Development, Fort St. George, Madras - 600008 Tamil Nadu.
28. Secretary, Department of Science, Technology and Environment, Government of Tripura, Agartala.
29. Director, Rural Development Department, Government of Uttar Pradesh, Lucknow.
30. Director,Non Conventional Energy Development Agency (NEDA), Vibhuti Khand, Behind PICUP Bhawan, Gomti Nagar, Lucknow - 226010.
31. Managing Director, U.P. State Agro Industries Corporation Limited, 2: Vidhan Sabha Marg, Post Box No. 261, Lucknow-226001
32. Secretary, Department of Social Welfare, Writers Building, Calcutta.
33. Director, West Bengal Renewable energy Development Agency, Government of West Bengal, LA Block Sector III, WBSEB Housing, B 4, Salt Lake City, Calcutta - 700091.
34. Chief Secretary, Andaman and Nicobar Administration, Port Blair.
35. Chief Engineer, Rural Works Department, Government of Arunachal Pradesh, Itanagar 791111.
36. Chief Administrator, Dadra and Nagar Haveli, Silvassa.
37. Director, Delhi Energy Development Agency (DEDA), 37, Institutional Area, Tughiakabad, New Delhi.
38. Project Director, Rural Development Agency, Dr. Kudchadkar Buildin 2nd Floor, Malacca Road, Panaji, Goa.
39. Administrator, U T. of Lakshwadeep, Kavaratti - 682888
40. Chief Commissioner, U T. of Daman and Diu, Daman.
41. Chief Executive Officer, Khadi and Village, Industries Commission (KVIC 3 Irla Road, Vile Parle (West), Bombay-400056
42. Managing Director, National Dairy Development Board, (NDDB), Anand-388001
43. President, All India Women's Conference, (AIWC), 6, Bhagwan Dass Marg, New Delhi -110001.

National Project on Biogas Development (NPBD)

Introduction

Biogas—a mixture of methane and carbon dioxide produced through fermentation of organic waste under anaerobic (oxygen-free) conditions—is a very convenient fuel in context of rural areas. Biogas provides both fuel and fertilizer, only one of which is possible with dung. It is a clean smoke- and soot-free fuel with efficiency comparable to that of LPG. Another feature of biogas is its versatility in that it can be used for cooking, lighting, motive power and even for generating electricity. In addition to the environmental and social benefits, it is also economically viable. A functional biogas plant is expected to save fuel equivalent of 4.8 tonnes of fuelwood per year per cubic meter.

Biogas programme

Biogas program is the oldest and largest renewable energy program in India. The first major technical achievement was the development of the floating-drum biogas plant by the Khadi and Village Industries Commission (KVIC) in 1952. By 1980, over 80,000 family size biogas plants had been constructed. With the launching of the National Project on Biogas Development (NPBD) in 1981-82, the program received a major boost. NPBD began as a part of the Sixth Five Year Plan. To provide impetus to the program, it was included in the Prime Minister's Twenty Point Program and was brought under the Department (now ministry) of Non-conventional Energy Sources in 1982.

Objectives of NPBD

- To provide clean and cheap source of energy in rural areas.
- To produce enriched organic manure for supplementing the use of chemical fertilizers.
- To improve sanitation and hygiene.
- To remove drudgery of women.

The Community, Institutional and Night Soil based biogas plants (CBP/IBP/NBP) Program was initiated in 1982–83, primarily to set up such plants at sites where there is high availability of cattle waste and use the gas produced for several end uses including cooking. The objection was to ensure that the benefits of the program reach the poor rural households who do not have enough livestock or space or sufficient funds to set up individual family size biogas plants. The MNES initially provided 90% of the cost as subsidy and undertook operation and maintenance of the systems for the two years after

which the systems would be handed over to the local community. A scheme of setting up large size biogas plants, linked with community toilet complexes, was added to the programme in 1995–96.

Program structure

Institutional arrangement

The Ministry has adopted a decentralized multi-agency, multi-model implementation strategy for the national program on biogas. At the state level, a nodal department (Department of Rural Development, Agriculture, Science and Technology etc.) is nominated to coordinate the activities under NPBD. Non–governmental organizations; like All India Women's Conference (AIWC), New Delhi and Aga Khan Rural Support Program (AKRSP), Ahmedabad; have been given separate annual targets to achieve. At the district level are the government bodies like BDO and DRDA, and also local entrepreneurs and rural NGOs, gram panchayats, dairy cooperatives etc.

In order to provide support for the implementation of the program, the ministry has created a network of seventeen Regional Biogas Development and Training Centers (RBDTC's) in the country. These centers impart training and provide technical support to the various groups of people involved in the implementation process. MNES has also set up eight regional centers to provide close guidance to the state nodal agencies and to monitor the progress of the program.

Financial arrangement

The task of target setting and disbursement of funds is done by MNES for each state/UT depending on size of the state, past achievements, performance etc. While 50 percent of the estimated outlay is given in advance to the implementing agencies at the state level, rest 50 percent is released after completion of 25 percent of the total physical targets allotted. The disbursement of funds at district and block levels varies with different program implementing agencies. The ministry and state nodal agencies provide several incentives to encourage the adoption of the technology under NPBD have been summarized under Box I.

Box 1. Incentives under NPBD

For end user

Central subsidy (Rs 1800-1500)
Bank loans

For field level

Turnkey fees of Rs 500 per plant
Rs 50 per plant for initiating village level acceptance

For state nodal agencies

Service charges
Staff orientation and training courses
Awareness campaigns
Gold and silver honorary shields

Note: A Turnkey worker is responsible for the entire process of biogas plant installation including motivating the beneficiary, arranging subsidy and loan, constructing the plant, commissioning, and ensuring a trouble free functioning of the plant for a stipulated period of three years.

The subsidy pattern is designed for different categories of people taking into account physical disparities existing in different parts of the country.

Subsidy pattern, 1995-96

Capacity of plant (meter cube)	NE states (excluding plains of Assam), Sikkim, J&K, HP, and 7 hilly districts of UP (excluding terai regions of two hilly districts), Andaman & Nicobar islands, Lakshwadeep	SC/ST, desert districts, small and marginal farmers, landless laborers, plain areas of Assam, terai region of two hilly districts of UP, Western Ghats and other notified hilly areas	All others
1	2800	2000	1500
2	3200	2400	1800
3 & 4	3500	2600	2000

Note: Biogas plants of 6 to 10 cubic meters capacity are eligible to receive the same subsidy amount as applicable for 3 and 4 cubic meters capacity w.e.f 1st April 1996.

In the initial years of NPBD, the subsidy was fixed so as to meet a substantial part of the total cost. However, now the subsidy has been gradually reduced to less than one third of the cost.

Monitoring and feedback

The monitoring and feedback on the program is done by the ministry to ensure the successful implementation.

Monitoring of NPBD

Nature of feedback/monitoring	Frequency	Involved implementing agency/official
Physical verification of all/5-10%/1-5% of the installed plants	Every month	Block Development Officer/District Level Officer/State Level Officer
Identification and rectification of dysfunctional plants	Every three months	State governments and implementing agencies
100% survey of plants in one block, randomly selected	Every year	Regional offices of MNES
Regular inspections	—	RBDTCs, with assistance from nodal departments, KVIC etc.
Information collection, feedback, performance monitoring	—	Turnkey workers, field functionaries and officers of nodal agencies at block, district and state level
Random sample inspections on operational performance	Every year	MNES and Regional offices

Independent research and academic organizations are also commissioned by the ministry to carry out evaluation studies and specific case studies.

Performance of the programme

Till 1994–95, over 21.89 lakhs biogas plants had been installed representing about 18% of the total estimated potential. Regarding the functional status of the plants, the evaluation survey by NCAER of the biogas plants installed under the Seventh Plan estimated that at the national level 66 percent biogas plants are in use, while in some states the functional level was as high as 90% (Karnataka and Gujarat) in other states it was as low as 60% (Bihar and UP). Some more results of the survey are given below:

Structural defects

The NCAER survey identified structural defects as the major reason for non functionality of the plants. Of these the more common defects, were:

- damages in foundation,
- cracks in dome, and
- cracks in digester wall.

Technical problems

The most prevalent technical (operational) problems were reported as:

- corrosion/leakage in pipeline,
- water accumulation in pipeline, and
- defects in burner.

Non-technical problems

The two non-technical reasons reported in the survey were:

- shortage of dung, and
- lack of interest on part of the owner.

Social problems

The most common social problem identified was the shifting of residence and of cattle sheds.

The survey also carried out opinion studies on whether the owners would be willing to get the defects rectified. The response obtained was largely negative with an overwhelming 76% of the respondents not agreeing to the prospect of rectifying the defects. The major reasons identified were:

(i) a majority felt that their plants cannot be rectified,
(ii) many were apprehensive as a result of the past failures, and
(iii) they did not know whom to contact for repair.

Till 1995, 1400 CBGs, NBGs and IBGs had been installed in the country. However, the functionality of the installed CBGs is less than 50% as per a study conducted by Agricultural Finance Corporation, Bombay in 6 states of the country covering 109 CBGs, IBGs and NBGs.

Review of the biogas programme

Though the biogas technology in the country is a century old, the actual installation of biogas plants started only as late as 1974. The pace of installation increased in 1981 when

the NPBD program was launched by the government. Today, India has about 2 million biogas plants of various sizes and capacities ranging from 1 meter cube to 150 meter cube. The figures on functionality of biogas plants vary from source to source. However, it is believed that 50% to 60% of the plants are in operation.

At the household level the following barriers are considered for those households that have adequate dung for a biogas plant:

1. The high cost of biogas plants is the primary problem, coupled with availability of fuelwood at almost zero cash cost to rural households. Since interest rates in rural areas are very high, it is difficult to expect all households with biogas potential to invest in a plant that does not provide any direct financial benefit.
2. In the government programme, there is little or no responsibility for ensuring the success of the plants built. There is neither any guarantee on the successful functioning of the biogas plant nor any efficient, reliable repair and maintenance service.
3. There is a severe shortage of trained manpower for building and servicing the biogas plants and for educating households on the operation and maintenance of plants.
4. There is inadequate funding at the national level to promote the programme.

As regards to Community plants, the theoretically estimated potential is of 5,57,000 plants, taking that each village in the country has potential for a CBP. In comparison, the achievement has not been significant. In many cases, after the first two years, the villagers were reluctant to take up the management of community plants and the systems went into a state of disuse. In others, the process began well but faltered ultimately due to political problems in the villages. The following are the major reasons for the inconsistent performance of the CBPs:

(a) Absence of community participation owing to factionalism or lack of interest on the part of the managing agency (panchayat, etc.);

(b) Improper planning in terms of dung estimation, site selection, gas distribution system, etc.;

(c) Inadequate maintenance resulting in irregular dung collection, underfeeding, slow disposal of slurry, etc.; and

(d) Inability of the poor households to pay even nominal monthly charges of Rs 30-50.

The major barriers to implementing community biogas programme are:

1. A large amount of funding is required for each village and there is lack of funding at the national level, even though the economies of scale operate at the community scale.
2. There is inadequate dung to meet the cooking energy requirements of the whole village and thus there is a general lack of interest in the programme at the village level since the ownership of cattle is unequal and skewed.
3. Government is not the right agency to implement the programme and the involvement of NGOs is marginal. No organizational arrangements exist to disseminate community biogas plants.
4. No institutional arrangement exists for village communities to take the initiative and responsibility for operating and managing the systems.

Of the states, Punjab and Gujarat have the most number of successful community plants. Case studies conducted on CBPs like Methan in Gujarat and Kheri Bhai Ki in Punjab show that the following factors would be critical for a community venture to succeed:

(a) The village or community should have socio-cultural cohesion with some uniformity in lifestyle and economic status; and/or,

(b) The village should have strong and committed leadership to motivate and unite the people. Given the stratification of Indian villages, it is difficult to envisage such conditions, and the success of CBPs remains an open issue.

In the initial years of NPBD, the failure rates were high due to poor quality control and lack of training of masons due to emphasis on meeting targets (overall target for NPBD is 200,000 plants per year). These targets were centrally decided and transmitted to the lower levels (state, district, block, etc.), and since achieving the numbers was the main objective, quality control, maintenance infrastructure, providing user awareness, etc. were not accorded the priority they deserved.

Mid-way through the programme, this was rectified to some extent by adopting a 'turn-key' approach. In this, unemployed and semi-employed rural youth were encouraged to take up biogas construction and they would be paid a 'turn-key' fee of Rs 500 per biogas plant as an incentive. Against this, a three-year warrantee would be given by these turn-key workers on the performance of biogas plants. They are also responsible for arranging subsidies, loans, etc. and for repairs, if any. This approach has been very

effective in ensuring quality construction and operation leading to success of the programme. This achievement could be seen manifested in the fact that turnkey entrepreneurs in states like Maharashtra, Gujarat and Andhra Pradesh are now able to promote biogas plants without availing subsidies or loans.

Potential and achievements

It has been estimated that the overall potential of the technology in the country is about 12 million plants. With only 21.88.885 plants been installed up to March. 1995: the percentage coverage of the overall potential comes to only 18.2%. At the current rate of funding and mode of dissemination, about 0.15 million biogas plants can be built every year implying another 60 years to build 10 million biogas plants.

Wherever the plants worked well, the qualitative as well as quantitative benefits have been well appreciated by the rural masses, as shown by various evaluation reports. Operational biogas plants has brought some relief to the women from the smoke and the time and energy spent in gathering and preparing biomass fuel. Households who had to purchase fuel earlier also benefitted in terms of monetary savings.

One of the main features of the programme has been the active involvement of NGOs in the implementation of the programme. Some large NGOs like Gram Vikas (GV) in Orissa, Aga Khan Rural Support Programme (AKRSP) in Gujarat, Center of Science for Villages (CSV) in Maharashtra and MYRADA in Karnataka have played a major role in the promotion of biogas. Action for Food Production (AFPRO), a large NGO based in New Delhi has also assisted NPBD by coordinating a network of grassroots level NGOs who implemented the programme. AFPRO was also instrumental in developing the design of *Deenbandhu, the most popular biogas plant model disseminated in India.*

Conclusions

Despite the achievements made and all the effort that has gone into the programme, the overall impact of biogas has been very small. One of the main reasons for this is that biogas has been dependent on cattle dung alone as a feedstock thus limiting its reach. Less than 20% of the rural households in the country own 4 to 5 cattle necessary to set up a biogas plant. Use of human waste, the main source of biogas in China which has the world's largest programme, is not possible on large scale due to religious and cultural inhibitions. The efforts to develop alternative feedstocks such as kitchen waste, water hyacinth, etc. have not progressed due to less emphasis on R & D in the programme.

The other limitation of biogas technology is the inability to generate gas under low temperature conditions (below 10°C). Thus, biogas plants are not suitable for colder regions, and produce less gas in winters in other regions as well. Again there is a need to develop bacterial cultures which could work under cold conditions. In fact, if such research developments can be pushed to succeed, the potential for biogas will be virtually unlimited.

Rural electrification

Introduction

Rural electrification in India is mainly through centralized grid electricity. However, there have been efforts in the past to demonstrate decentralized renewable energy systems for meeting the electricity needs of the rural people. These are primarily focussing on remote and inaccessible areas of the country where extending grid lines is very costly. The main agencies involved in rural electrification are the Rural Electrification Corporation, State Electricity Boards (SEBs), and Ministry of Non-conventional Energy Sources (MNES).

Rural electrification through grid electricity

Rural Electrification Programme (REP)

The Rural Electrification Programme (REP) was initiated by the Government of India as early as 1952. The objective of the programme is to promote economic development and improve the quality of life of the rural masses. The productive use of power in rural areas has been repeatedly emphasized by giving preference to pump energisation. The main programmes under REP are:

(a) Village electrification, and

(b) Pump energisation.

Another component of REP is the System Improvement Programme in electrified villages. The aim is to reduce distribution losses and overcome the problems of low voltage and supply interruptions. Load intensification programmes have also been taken up for developing load in the electrified villages.

Institutional set up

Rural electrification corporation (REC)

The Rural Electrification Corporation (REC) was set up in July 1969. The main functions of REC are:

(a) To finance rural electrification schemes in the country,

(b) To promote and finance rural electrification co-operatives in the country,

(c) To finance and/or execute works on small/mini/micro hydro generation projects,

(d) To finance survey and investigation of projects falling in the ambit of REC, and

(e) To promote, develop and finance viable decentralized power system organizations in cooperative, joint, private sector, panchayat and/or local self bodies.

During the Fifth Five Year Plan (1974–78), the Rural Electrification Programme was linked with Minimum Needs Programme (MNP). The objective was to provide basic amenities to rural masses by extending the benefits of electricity to as large a section of the population as possible. With this linkage, the focus of REP shifted to village electrification. Funds are provided for village electrification to states under their state plan in addition to funds released as loans to state through REC. These area based rural electrification schemes, which are implemented by SEBs, are scrutinized by REC which sanctions loans and monitors the progress of the schemes. REC keeps the accounts and is responsible for collection of loans from SEBs and their remittance to the Government of India.

Rural electric co-operatives

The rural electric co-operatives were set up with the objective of making the villagers contributors in the programme in terms of sharing cost of rural electrification and providing free labour for construction. Presently, 37 Rural Electric Cooperative Societies are functioning in the country with the financial assistance from REC. However, the program has not been able to make an appreciable impact presumably because of conditionality of tariffs imposed on the co-operatives by the SEBs.

Other programmes

Special Programme - Agriculture (SPA)

The strategy for rural electrification from the Sixth Plan (1980-85) onwards was to extend the rural electrical infrastructure to serve agriculture and rural industries more effectively. The objective was to generate employment and meet the basic needs of the rural population. Rural Electrification Corporation took the initiative to tap funds from the banking sector and commercialize pumpset energisation programmes by collaborating with the National Bank for Agricultural and Rural Development (NABARD) and commercial banks in a new programme called 'Special Programme- Agriculture'. This provided a big boost to the pumpset energisation programme.

Kutir jyoti programme

'Kutir Jyoti' programme was launched in 1988-89 to provide single point light connections to the rural households living below the poverty line.

Future plans

According to REC sources, about 85000 villages in the country are yet to be electrified. The REC proposes to electrify 65000 villages through the conventional sources, while the remaining 20000 villages will be provided power by tapping non-conventional sources. About 1.6 million households have benefited from Kutir Jyoti program and some 6.25.000 more connections will be released in 1995–96. The plans of REC in the near future include:

1. Accelerating rural household electrification;
2 Stepping up rural industrialization through adequate and assured electric supply;
3. Accelerating electrification of tribal areas and provision of street lights in Harijan Bastis;
4. Initiating measures and special schemes for correcting problems of low voltages and frequent breakdown in rural areas;
5. Providing additional resources for expanding the 'Kutir Jyoti' programme;
6. Continuing thrust on pumpset energisation program;
7. Promoting use of innovating, cost-effective and energy efficient technologies;
8. Promoting small hydel generation for augmentation of rural power supply and electrification of remote villages; and
9. Promotion of suitable decentralized power distribution systems - strengthen existing RE Co-operatives and promotion of new viable co-operative and other distribution models at panchayat level.

Performance of REP

Till March 1996, the Corporation has contributed to the electrification of 2.93 lakh villages and energisation of 65.21 lakh pumpsets. The 30,662 schemes sanctioned by REC cover electrification of about 3.19 lakh villages and energisation of over 64,16 lakh pumpsets. As per the latest annual report of REC, 86% of villages in the country have been electrified. Many states such as Andhra Pradesh, Gujarat, Goa, Haryana, Himachal Pradesh, Karnataka, Kerala, Maharashtra & Punjab have the distinction of 100% village electrification. On the other hand, states like West Bengal has only 73% villages electrified, the lowest level achieved by Bihar with only 70% villages electrified. The unelectrified villages are mostly in those states where the SEBs are not financially strong. These villages are located in the remote, far flung and backward areas and are mainly concentrated in four states of Uttar Pradesh, Bihar, Orissa and West Bengal. Till March 1996, over 2.12 million connections had been released under the Kutir Jyoti programme.

Review of REP

The performance of village electrification through centralized commercial utilities can be evaluated by adopting two approaches:

(a) *No. of villages electrified* : 86% of the 0.55 million villages have been electrified.
(b) *No. of households electrified* : Only 31% of the total rural households have been electrified.

There has been a poor progress in domestic and street lighting in the rural areas of the country. This is explained by several factors:

High Cost of grid extension

Extension of grid lines to villages has been an unremunerative proposition for the SEBs. The cost of extending supply through 33 kV and 11 kV lines has also been increasing. About 1.5 million rupees is spent for every km length of new connection of 11 kV single circuit line. In addition to the high investment, there are very few subscribers for power in villages.

Low electricity tariffs and subsidized electricity

The state electricity boards have been unable to recover their overall average cost of generation and supply, and the deficit has increased over time. While the average cost of electricity for the SEBs was 150.4 paise/kWh in 1993-94, the overall average tariff charged by the various boards was 121.0 paise/kWh in the same year. These low tariffs have contributed significantly to the losses of state electric utilities.

High Transmission and Distribution losses

The high T & D losses could be attributed to the fact that the expansion and strengthening of T & D has not kept pace with additions to generating capacity. Infact, in certain instances the utilization of generation capacity has been reduced only because the T & D network is not reliable. In absence of adequate regional and national integration of the T & D network, power supplies cannot be optimized. This has aggravated the problem of power shortages in certain parts of the country especially in the rural areas. Other factors contributing to high T & D losses include: too many transformation stages, improper load distribution, extensive rural electrification and pilferage and unmetered power supply.

Inability to pay initial and recurring cost of electrification

The consumer financial sector is not well developed in rural India. Consumers in rural

areas usually have a fixed budget for all their investments, including end-use efficiency. The rural poor do not have the capacity to buy commercial energy even if it is available. Connections are released on demand for which earnest money (differs from state to state) is to be paid. Sometimes the villagers are not in a position to pay for the connection or at times they are not willing to incur additional expenditure.

Inadequate and erratic power supply

In a micro-level study the grid power supply for village Ungra in south India was monitored for 12 randomly selected months from 1991 to 1994. The results of this monitoring exercise showed that in nearly half of the months either there was no power supply or there was disrupted power supply during the crucial evening hours (6-10 pm) for over 50% of the days. Also, the voltage was less than 150 V for 41% of the observation time.

Classification of village as "Electrified"

A village even with a single point connection is classified as "electrified". The argument against this classification is that a single point connection in a village does not make all the households electrified. There are villages (data not available) through which transmission lines pass, yet none of the households receive power. Also, even though there is no national/aggregate data available to support the argument, data from certain states like UP and Bihar show that only 9.3 and 4.4% of households are actually electrified.

Village electrification through renewable energy sources

Demonstration programmes promoting rural electrification through renewable sources of energy are largely under the Ministry of Non Conventional Energy Sources. These are mainly decentralized renewable energy systems for providing electricity to remote and inaccessible areas of the country. However, these have found place even in the villages with grid electricity. A majority of these technologies cater to the end use of lighting. The various programmes of MNES for promoting such decentralized renewable energy systems for rural electrification are given in the following sections.

Family and community biogas programme

The National Program on Biogas Development (NPBD) is focussed at setting up of family size biogas plants for providing clean and non polluting source of energy and rich organic manure to the farmers and to reduce the drudgery of women in rural areas. However, the family type biogas plants can meet the lighting requirements of a particular household only

to a limited extent. Family sized biogas plants are more suitable to meet the cooking energy needs but not for generating electricity for village use.

Programme on Community/Institutional/Night soil based biogas plants

The limitations of a family size biogas plant can be largely overcome with large size community biogas plants that could meet the needs of small farmers with very few livestock and little space. Such plants can also be set up for electrification of villages.

The CBP/IBP/NBP programme was initiated in 1982-83 with the objective of setting up large sized biogas plants in the villages and at institutions having large quantities of cattle waste. The objective was to utilising the gas for the operation of engines for mechanical and electrical power generation.

Floating metal drum type plants are installed for large-sized community and institutional biogas plants based on cattle dung. For night soil biogas plants, both floating drum and fixed dome designs with separate gas storage provision have been found suitable. Besides the State Governments and the nodal agencies, the non-governmental organizations have been involved particularly in the promotion, installation and operation of night-soil based biogas plants with twenty years guarantee for operation and maintenance.Central financial assistance is given for the setting up of community, institutional and night-soil based biogas plants (Table 1).

Table 1. Rates of Central financial assistance

Capacity of Plant (cu.m. of gas production per day)	CBP	IBP		NBP
		Goshalas/ Pinjrapoles, organizations/societies; Institutions of Central & State Govts; Co-operatives, or Trusts or other institutions tied to such bodies	Private and Profit-making institutions and others	
8	—	—	—	22,000
10	—	—	—	25,000
15	44,000	35,000	22,000	40,000
20	56,000	45,000	28,000	50,000
25	70,000	55,000	35,000	60,000
35	100,000	80,000	52,000	560,000
45	150,000	95,000	64,000	625,000
60	170,000	115,000	76,000	800,000
85	200,000	140,000	94,000	—

Community toilet complex-linked biogas plants
Biogas plants of capacities ranging from 35 to 60 cubic metres linked with community toilet complexes are eligible for higher financial assistance, if the local bodies provide land free of cost and meet the cost of construction of the toilets. Private entrepreneurs and NGOs are involved in the operation and maintenance of these complexes, including the biogas plants, on a pay-and-use basis for a period of at least 20 years.

About 1400 community, institutional and night soil based plants had been installed in the country by 1994–95.

Community biogas plants are still at a demonstration stage in India. A demonstration of the use of CBGs for generating electricity for a village as a unit is given as a case study in the Annexure.

Demonstration & utilisation programme: solar photovoltaic for home and street lighting

Under the Demonstration and Utilisation Program of MNES, the solar photovoltaic programme is being implemented through the socially oriented and market oriented schemes.

(a) *Market oriented scheme* is implemented through IREDA by providing soft loan assistance for SPV systems. In addition, IREDA is implementing the World Bank assisted SPV Market Development Programme.
(b) *Socially oriented scheme* involves central subsidy for the installation of SPV systems. These include systems like portable solar lanterns, fixed type domestic lighting systems, street lighting systems, community lighting/TV systems and small village level power plants. In addition, specific projects for the following categories of beneficiaries are eligible for assistance under this scheme: a) Scheduled castes, b) Scheduled tribes, c) Fishermen, d) Handloom workers, e) Village artisans, and f) Handicapped persons. The details of the solar lantern programme are given in the Annexure.

During 1995–96, 680 street lighting systems, 7470 domestic lighting systems, 44938 solar lanterns and power plants of an aggregate capacity of 89 kWp were installed.

Biomass gasification demonstration program for rural electrification
Gasifiers can be used for electrification of small and remote villages by utilising locally available biomass. Woody-based biomass gasifier technologies of 5 HP and 10 HP are being promoted for water pumping application while those of 3 KW to 500 KW are being

popularised for power generation. The government is providing financial assistance of Rs 10,000 plus Rs 100 per KW for preparation of Detailed Project Report (DPRs) and up to 75% of the total cost of gasifier systems, dual-fuel engines and alternators. The Rural Electrification Corporation (REC) is expected to provide funds for the laying of electricity distribution. About 1600 gasifier systems of 16 MW equivalent capacity had been installed up to 1994–95.

Performance of the programme

No detailed investigations are available at present on the performance of the gasifier programme. The findings of a short study in four states are presented below, which gives mainly the extent of gasifiers in use. Out of the 539 gasifiers only 79 were inspected: of this only 19 per cent of the systems were being used in the dual-fuel mode and 6 per cent of the systems were being used in both dual-fuel and diesel-along mode. The rest were being used in a diesel-alone mode, not used at all, or not yet commissioned. The use level was poor with respect to the other capacity systems.

Case study of wood gasifiers supplied in Sirsi

In the Sirsi administrative block of Karnataka in South India, seven wood gasifiers of 3.7 kW capacity were installed out of the national programme of about 800. All seven were installed to pump irrigation water during the summer months in the Areca garden locations away from the grid.

Out of the six gasifiers, four had been used for 4 years, and the other two were used for 2 years. Three of the systems were used for nearly 2000 hours. Sirsi is a high-rainfall area and receives 300 cm of rainfall annually. Thus irrigation is required mainly during the summer months. All the farmers reported substantial diesel replacements.

Use of all the gasifiers was discontinued after they developed problems, such as cracks in the nozzle. All the farmers complained of the cumbersome procedure of operation, especially wood preparation. Interestingly, however, all wanted to use the system if their gasifier had performed well and if local servicing and repair facilities were available. This gives hope that if a user-friendly design coupled with adequate servicing and repair infrastructure is provided, farmers will be keen to use them as they see clear advantages for locations away from gird transmission lines.

Source: Subramanya *et al.* 1993. Development strategies for effective dissemination of gasifiers, sterling engines. in Recent advance in biomass gasification and combustion (ed. P J Paul and H S Mukunda). Interline Publishing, Bangalore, India.

Potential and achievement

When compared to the potential for power generation of 17 000 MW, the present installed capacity (6.5 MW) is insignificant and the performance is even poorer. In India there are over 9 million electric pumpsets and 5.5 million diesel engines used for pumping irrigation water. If a user-friendly and reliable gasifier system was available with appropriate incentives, many of the 14.5 million pumping systems could be candidates for potential replacement by wood gasifiers. The reasons for low achievement and poor performance are:

Subsidized electricity and diesel. Farmers in the country have a choice of options for irrigation-water pumping—electricity-powered pumps or diesel engines. Diesel fuel and electricity are subsidized in India; in fact, electricity is virtually free for agricultural pumping. Both diesel and electric systems are widely used and an extensive infrastructure is available for supply and servicing in all parts of the country. Thus any new option would have to be better than the existing systems in terms of cost, convenience of operation, and reliability.

Inappropriate locations for gasifier demonstration units. Although it is not documented in any report, it is common knowledge among researchers in India that many of the gasifiers were supplied to farmers who already had electric pumpsets or diesel engines and who did not really need a gasifier. The farmers accepted them since the gasifier-diesel engine unit was highly subsidized. However, the overall rate of acceptance was low. If the demonstration gasifier units had been supplied to farmers in remote areas, who had no access to grid power, the rate of acceptance or use level would certainly have been different.

Pumping—a wrong end use?. Possibly pumping irrigation water was an inappropriate end use to start dissemination as the competing option of electricity is highly subsidized. The gasifier system would have possibly worked in situations where there was no significant subsidy available and grid electricity was not present.

Botheration factor. In the case of electric pumpsets, all that the farmer has to do is press a button to lift water. For diesel engines the farmer has to buy diesel, fill the tank, and start the engine. Gasifier operation involves a range of activities, the most cumbersome processes being: obtaining wood, cutting it to the appropriate size, drying it in the sun, and loading it into the gasifier before starting the system. This botheration factor is a deterrent, especially in locations where easier options are available.

The technology is still in the development stage. It has yet to be made user-friendly and there are potentials for cost reduction and improving the life of the system.

Review

The progress of village electrification through non-conventional energy sources has been rather disappointing though household electrification with SPVs has made some headway. However, demonstration projects trying to meet all the energy needs through a local centralized solar power plant in developing countries have largely failed. The reasons for failure include the limited central power availability and uncontrolled individual demand. Also, the scaling up of a solar power plant has not lowered the per kWh cost in rural areas.

As a result of the failure of solar power plants, individual autonomous solar power supply packages, popularly called the SHS or the Solar Home Systems, have found their way into the rural market in a big way. These SHS are able to meet the power needs of an individual appliance or function e.g.a solar lantern, a street lighting unit etc. In line with above, the PV program in India has been restricted to street lighting or domestic lighting of individual households through SHS.

The field performance of PV lighting systems has been poor as is reflected from a 1990 survey done by Administrative Staff College. The survey showed that of the 4651 street light systems installed in 5 states, 37% had failed due to technical problems and 10% due to theft or vandalism. The poor performance of PV program can be attributed to:

- non participatory beneficiary approach,
- insufficient infrastructure for monitoring and maintenance,
- lack of staff and user training on system maintenance,
- non involvement of local manufacturers,
- non availability of spares, and
- poor consumer education.

According to available information, no reliable and comprehensive village-wide power supply system was set up to cover all the households and pumpsets in a village through renewable appropriate strategy. Poor clarity of objective and clear identification of the agencies responsible for implementation and monitoring has been a major drawback. This highlights the need for according priority to survey and identification of remote villages within a period of 3–4 years which can not be economically connected to the grid. Following this, there should be an assessment of availability of local sources of non-

conventional energy in such areas or villages and the economic viability and sustainability of such arrangements. Accordingly, suitable strategies should be developed with local involvement.

ANNEXURE

Biogas for lighting - Case study of Fateh Singh Ka Purwa

The first large size community biogas plant was installed in the village Fateh Singh-ka-Purwa (West U.P.) in 1978. This plant was installed as an experiment to study the technical and socio-economic problems faced in the installation, operation and maintenance of a community biogas plant.

The plant consisted of two inter connected biogas plants (35 and 45 cubic meter sizes) and two dual fuel engines (5 HP and 6 HP size) operating on 80 percent gas and 20 percent diesel oil. The plant was so designed so as to fulfill the lighting needs of all households besides providing for the cooking needs of all households and the energy requirements of 1 tubewell, 1 flour mill, 1 thresher and 1 chaff cutter. Gas was supplied to all households for 5 hours every day during fixed hours in the morning and evening. Street lighting was provided at twelve points in the village and all households were provided electric connections.

Initially, the entire cost was met by the government. It was envisaged that after one year of operation, operating and capital costs will be recovered from the villagers through levy of charges for gas supply.

A local management committee consisting of representatives from amongst the villagers was constituted for management of the plant. Besides, a full time worker, financed by the government, was employed for operating the plant and for collecting dung and ensuring the disposal of slurry.

The main reason for the failure of the plant was more to do with attitudinal aspects rather than technical. Adequate number of households did not participate and the villagers felt that the gas supply was inadequate to meet their requirements. Some farmers were not convinced of the usefulness of slurry as manure, therefore, contributed only a portion of the dung. Besides, many large farmers were not ready to contribute adequate dung because the gas supply was not given in proportion to the amount of dung contributed. On the other hand, the authorities were not willing to increase the gas supply since the villagers refused to pay for the gas. Above all, a particular section of the community was not cooperating due to existing groupism with the village community.

ANNEXURE

Solar lantern programme

For solar lanterns, all categories of individual beneficiaries and non profit organisations/institutions have been made eligible during 1995-96 for availing Central subsidy.

The following policy changes were made for solar lantern programme during 1995-96:

- In view of the reduction in the cost of solar lantern, the Central subsidy has been reduced from Rs. 2000 to Rs. 1500 per lantern;
- The specifications of solar lanterns were reviewed and modified after taking into account the latest developments in the field of SPV technology, batteries, electronics and lamps. Four different models of solar lanterns were approved for implementation under the Programme;
- Testing and certification of solar lanterns samples from the Solar Energy Center/other approved test centers were made mandatory for participation under the Programme;
- Restrictions on the eligible beneficiary categories for availing Central subsidy under the scheme were removed and all categories of individual beneficiaries and non-profit organisations/institutions were made eligible for the subsidy;
- For speedier implementation of the solar lantern programme, the State implementing agencies were advised to open new distribution channels by tieing up with outlets like Super Bazaars, Kendriya Bhandars, Co-operative Societies and NGOs.

Integrated Rural Energy Planning Programme (IREP)

Introduction

The Integrated Rural Energy Planning Programme (IREP) was initiated by the Planning Commission as a pilot project during the Sixth Five Year Plan. The programme was later transferred from the Planning Commission to the Ministry of Non-conventional Energy Sources in April 1994.

The aim of the programme is to provide planned inputs for meeting energy needs of rural areas through an optimum mix of energy sources. IREP consists of the following elements:

(a) Provision of energy for meeting the basic needs of cooking, heating and lighting, especially for the weaker section, by utilising locally available energy resources to the extent possible;

(b) Provision of energy as the critical input to the economic development of rural areas which would result in the creation of employment, increase in productivity and income, and in accelerating the process of decentralised development. In this category, sustainable agricultural production as well as promoting sustainable rural development activities are included;

(c) Ensuring large-scale people's participation in the planning and implementation of the programme by:
  - the direct involvement of panchayats, voluntary and non-official bodies and institutions
  - the establishment of self managed organisations and other appropriate people-oriented arrangements at the micro-level;

(d) Setting up and strengthening of the mechanisms and coordination arrangements that would effectively link rural energy with the national and State level planning;

(e) Financing of the programme by supplementing the available Central and State budgetary support with resources to be mobilised by the panchayats and other local bodies.

Programme details

An area based approach is adopted in the programme where a block is taken as the planning unit. The programme has two components:

Central sector

The Central Sector component includes the Centrally Sponsored Scheme for developing capabilities in the States and UT's for preparing and implementing integrated rural energy plans and projects. For preparation of this plan and its execution, the Centrally Sponsored Scheme provides grants-in-aid for professionals and supporting staff in the State and block level IREP cells. The Centrally Sponsored Scheme also provides financial support for creation of technical back up units at the State level and at the District level, which is utilised for training, maintenance and developmental activities in the State and District. National level training programmes at various levels are organised at the one national and four regional training centers set up under the programme.

State sector

In the State sector component, separate funds are provided from the States for the programme. These funds are utilised for the implementation of the IREP plan. This includes funding demonstrations activities, provision of financial incentives for various energy devices etc. Funds and resources from other ongoing schemes and programmes for energy and rural development in the IREP blocks are also utilised for realisation of the energy plan. Both conventional and non-conventional energy systems and devices, including devices for energy conservation are propagated through the programme.

As part of the state sector component, the main devices promoted in the IREP blocks include pump sets for efficient utilisation of electricity, energy efficient diesel pumpsets, pressure cookers, wind mills, solar cooker and heating devices, biomass, improved chulha, improved bullock carts, improved kerosene stoves, frictionless foot valves, cycle trailer, fluorescent lamps and individual biogas plants.

A national and four regional training-cum-R & D centers have also been established under the programme. The national level center - Center for Integrated Rural Energy Planning (CIREP) was set up in Bakoli village in Delhi in co-operation with the Delhi Administration, and with technical and financial support of the Planning Commission under the centrally sponsored scheme for IREP. The four regional centers are located in Lucknow (Uttar Pradesh), Bangalore (Karnataka), Kheda (Gujarat) and Shillong (Meghalaya). Besides these, state-level technical back-up units have been set up in selected institutions for providing technical support in the planning and implementation for the programme. Also, district level IREP back-up units have been set up through ITI/ polytechnics in selected IREP blocks to provide technical assistance.

Performance of IREP

During the first two years of the Eighth Plan, IREP was extended to 86 and 100 blocks respectively. As on March 31, 1995 the programme had been extended to a total of 552 blocks. Major emphasis is laid on building the capabilities of the State/UTs personnel through education and training of the potential beneficiaries as well as of those directly and indirectly involved with the planning and implementation of the IREP plans and projects. The programme is also being made more broad based. Necessary steps have been taken to coordinate various rural energy programmes such as biogas, improved chulha, biomass, solar thermal, solar photovoltaics etc. implemented by the Ministry with IREP.

Review of IREP

Lack of co-ordination

A major impediment in implementation of IREP programme are the sectoral barriers and lack of co-ordination among the concerned energy supply and use departments/ agencies at different levels - national, state, district and grass-roots.

Lack of suitable extension mechanisms

Another limitation is the lack of suitable extension mechanisms at the grass roots. Such mechanisms can create awareness in people about the programme and provide technical and financial support in the installation, operation and maintenance of different energy devices.

Low purchasing power of end users

Affordability among the potential beneficiaries is also a major constraint. Mechanisms are required for mobilizing resources not only from the budgetary support provided by the Central and State plan funds but also through local self government bodies, including the direct involvement of the people.

Poor participation

Organizing participation of potential beneficiaries is required to be done both by the government machinery and voluntary organizations, educational institutions, *mahila mandals* and charitable organizations. The involvement of potential beneficiaries can be further ensured by linking IREP with other rural development programmes. The active association of women could be ensured by linking IREP with DWCRA , health and family welfare programmes, ICDS, etc. The literacy programme, can also create awareness about the IREP programme.

Low retention of professional staff for training

Though the training course is now well established, attracting and retaining professional staff in IREP cells is a problem as the participants often return to their parent departments. Training exercises thus have to be repeated for the new incumbents. Owing to lack of a regular cadre and promotional avenues, qualified professionals are often reluctant to join the programme.

Overburdening of Institutions

The functioning of IREP cells in state/UT nodal departments, which are currently implementing the programme, poses an institutional problem. These departments are burdened with other schemes and often tend to give low priority to IREP. Moreover, the staff allocated to the IREP cells as part of the centrally sponsored scheme have additional tasks and thus have little time for IREP. In many cases, the block staff functions from district headquarters resulting in lack of regular interaction between the IREP staff and the potential beneficiaries.

Conclusions

Despite the constraints, a sound base for the implementation of the programme has now been created. The demonstration and extension efforts have created awareness regarding the programme and led to a widespread interest amongst the rural population, especially in IREP blocks, in various alternative energy sources and their efficient utilization for meeting their energy needs.

Urjagram programme

Introduction

The programme was started during the Seventh Five Year Plan. The idea was to create a model village where most of the energy needs can be met using renewable energy systems. The *Urjagram* Programme is aimed at harnessing the locally available renewable energy resources like solar, wind, biomass etc. in an integrated manner. This would help in:

(a) supplementing the energy supply options, and

(b) bringing about energy self-sufficiency in villages.

The programme also envisages:

(a) creation of rural energy data base for planning and implementation of the *Urjagram* projects,

(b) meeting energy requirements of villages through the use of a mix of NRSE systems,

(c) evaluation of technical performance of the systems/ devices, and

(d) multilevel planning studies.

The projects contribute not only to meeting the energy requirements of the villages but also leads to generation of economic activities, higher incomes and creation of employment at the village level.

Urjagram projects

The *Urjagram* projects are implemented through State nodal agencies with the involvement of village Panchayats, *Urjagram* Samities, village co-operatives, unemployed youths, educational institutions, research organizations, industry and voluntary organizations. The projects are executed by the State nodal agencies with the help of villagers for an initial period of 3 years. After imparting sufficient training to the villagers and unemployed youths, the systems are handed over to the village Panchayats or the *Urjagram* Samitis, as they are commonly referred to.

A total of 241 *Urjagram* projects have been completed so far in 17 States and UTs. The State-wise break-up of *Urjagram* projects as on 31.1.96 is given in the Annexure. The *Urjagram* projects are periodically monitored and inspected by MNES officers and regional project officers.

Present status

During 1995-96, no new *Urjagram* projects and energy surveys were taken up. The projects sanctioned so far have been monitored and the funds are being utilised only for meeting the old commitments. The *Urjagram* project is being coordinated with the IREP, which has been transferred from the Planning Commission to the Ministry of Non-Conventional Energy Sources with effect from 1.4.94 with due emphasis on the promotion of renewable energy devices for rural development.

Review of *Urjagram* projects

An impact assessment study of *Urjagram* projects sponsored by MNES was carried out by Tata Energy Research Institute (TERI), New Delhi and the Operations Research Group (ORG), Baroda. This study included 30 *Urjagram* projects in Northern/Eastern, Southern/Western region of the country. The study suggested various measures for better implementation of *Urjagram* projects. Some suggestions are given below:

1. Selection of Urjagrams should be strictly based on the feasibility study,
2. The devices should be geared to meet desired end uses in long term. For this, they should be selected in consultation with the villagers and adapted according to their specific requirements and local practices,
3. It is necessary to ensure quality in the devices that are installed under Urjagrams,
4. The Technical Backup Unit should be located near the *Urjagram*. The implementing agency has to play an effective and dynamic role,
5. There should be adequate emphasis on awareness generation and training,
6. As the implementing agency has to play a dynamic role in *Urjagram*, training to implementing agency officials - (National level workshops etc.) should be given due importance, and
7. To increase the ability to pay for the energy services in the first phase all energy Interventions should be linked to revenue or employment generation in the *Urjagrams*.

ANNEXURE

Status of Urjagram projects as on 31.1.96

State/ UTs	Completed	Under implementation
Andhra Pradesh	4	16
Arunachal Pradesh	-	1
Assam	1	2
Bihar	9	5
Gujarat	22	11
Haryana	5	1
Himachal Pradesh	1	1
J & K	2	2
Karnataka	3	4
Kerala	-	3
Madhya Pradesh	22	11
Maharashtra	61	20
Orissa	7	11
Punjab	6	3
Rajasthan	8	18
Tamil Nadu	34	21
Tripura	2	-
Uttar Pradesh	51	34
West Bengal	6	4
Total	244	168

Session III

Overview of Renewable Energy Technologies

The participants will be breifed on various aspects of renewable energy technologies (RETs) that are being disseminated in the country on a large scale. The working principle of each of these RETs and their relevance for the rural areas will also be discussed.

Contents

- Biogas technology
- Improved cookstoves
- Biomass gasification
- Solar thermal applications
- Solar photovoltaic technologies
- Small hydro power systems
- Wind energy
- Energy plantations

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Biogas

The technology

When any organic matter, such as cowdung, crop residue, and kitchen waste is fermented in the absence of oxygen, biogas is generated. Biogas contains combustible methane (around 60%) along with carbon dioxide, and traces of other gases. Biogas production is a chemical process occurring in stages during which different bacteria act upon the organic matter resulting in the formation of methane and acids.

Factors influencing biogas production

The main factors that influence biogas production are:

pH level of feedstock

A biogas plant works optimally at a pH level of 7 or just above (neutral solution)

Ambient temperature

The plant functions at an optimal level at a temperature of around 35 °C. At low temperatures, bacterial activity slows down resulting in substantial decrease in gas generation. The bacterial activity completely stops at temperatures below 10 °C.

Carbon-nitrogen ratio of the feed material

The carbon-nitrogen ratio of the feed material is also an important factor and should be in the range of 20:1 to 30:1. Cowdung has a C-N ratio of 25:1 and is therefore considered ideal for maximum gas production.

Solid concentration in the feed material

Solid concentration in the feed material is also crucial to ensure sufficient gas production. It is also important for easy mixing and handling of the feed material. 8-10% of total solids in the feed material is the normal value required. Cowdung has a solid concentration of about 20%, and therefore, it is recommended that dung and water are mixed in a 1:1 ratio.

Quantities of feeding material

One kilogram of dung produces about 40 liters of biogas, and thus, in order to produce two cubic meters (2000 liters) of gas per day, which is required to meet the cooking needs

of an average family of four to five members, a mix of 50 kg of dung and 50 liters of water should be fed into the plant everyday.

Hydraulic retention time (HRT)

Hydraulic Retention Time (HRT) is the number of days the feed material is required to remain in the digester to begin gas production. This is the most important factor in determining the volume of the digester which in turn determines the cost of the plant. The larger the retention period, higher the construction cost.

In India, different HRTs are recommended for three different temperature zones. For all the approved models under NPBD, the plant dimensions, requirement of materials for different digester capacities etc. are available for different HRTs (Table 1).

Table 1. HRTs for different temperature zones

Zone	Average ambient temperature	HRT (days)	Approximate regions
I	>20 °C	30	Andhra Pradesh, Goa, Karnataka, Kerala, Maharashtra, Tamil Nadu, Pondicherry and Andaman & Nicobar Islands
II	15-20 °C	40	Bihar, Gujarat, Haryana, Jammu region of J & K, Madhya Pradesh, Orissa, Punjab, Rajasthan, Uttar Pradesh and West Bengal
III	<15 °C	55	Himachal Pradesh, North-eastern states, Sikkim, Kashmir region of J & K, and Hill districts of UP

Applications of biogas

Biogas can serve as a convenient fuel that can be used for a variety of applications, such as cooking, lighting, and motive power. The slurry that comes out of a biogas plant after the gas is produced, can be used as an organic manure in the fields to augment soil fertility. It can be used; through a specially designed mantle, for lighting too. Further, biogas can partially replace diesel to run IC (internal combustion) engines for water pumping. This would not only reduce dependence on diesel which is mostly imported in India, but also help in reducing the carbon pollutants which adversely affect the atmosphere. Dual-fuel engines (80% biogas and 20% diesel) are now commercially manufactured in India. Biogas can be similarly used to produce electricity, though this has not been attempted on a large scale in the country so far. Thus, biogas technology produces fuel as well as fertilizer, while only one of these is possible if dung is used in its original form. The versatility of biogas is its greatest advantage as a source of energy for the rural areas.

Efficiency of biogas system

Studies show that the biogas system is less efficient than the conventional system as far as cooking energy production is concerned (See Figure 1).

It can be seen that with poor quality burners, cooking energy production through the biogas route is 38% less than that of the traditional route and with good quality burners it is about 15% lesser. Biogas systems would be suitable where dung cakes are used for cooking energy instead of manure. Also, Biogas systems are not automatically more efficient in utilising energy from cattle dung. They are efficient only if they work with longer retention times in order to produce more gas per unit of feed material with a high methane content.

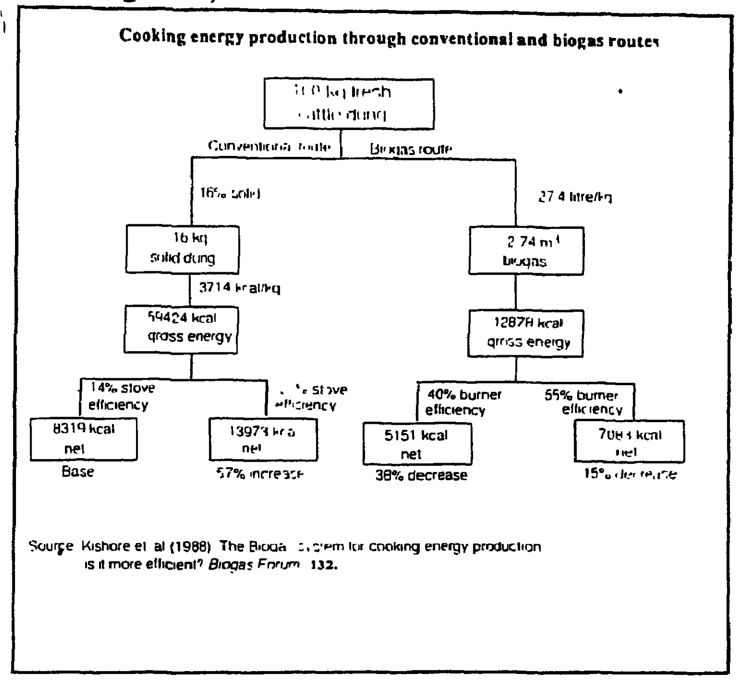


Figure 1

Also, efficiency of the system would automatically increase if the gas storage is airtight to avoid losses. Accordingly, clean burners working with proper gas-air ratio will further increase the efficiency of the system.

Benefits of biogas

1. Biogas technology makes optimal utilisation of the available natural resources;
2. It produces nutrient-rich manure;
3. It is a convenient cooking fuel;
4. In terms of cost, biogas is cheaper, on a life cycle basis, than conventional biomass fuels (dung, fuelwood, crop wastes, etc.) as well as LPG, and is only fractionally more expensive than kerosene;
5. To the housewife, biogas is easy to use and saves time in the kitchen;

> Based on the effective heat produced, a 2 cubic meter biogas plants could replace, in a month, fuel equivalent of 26 kg of LPG (nearly two standard cylinders), or 37 liters of kerosene, or 88 kg of charcoal, or 210 kg of fuelwood, or 740 kg of animal dung

6. Cooking on biogas is free from smoke and soot, and can substantially reduce the kitchen related health problems, which are otherwise quite common in most rural areas in India where biomass is the chief source of fuel; and
7. Use of biogas also reduces the drudgery of women in gathering fuelwood.

While biogas has multiple benefits at the individual family level, it also has several qualitative and quantitative benefits at the societal level. Firstly, a shift to biogas from traditional biomass fuels results in less dependence on natural resources such as forests, checking their indiscriminate and unsustainable exploitation. Since dung is collected systematically when used in biogas, the village environment can be kept clean and hygienic. The other advantage is that unlike centralized systems such as thermal power plants and fertilizer factories, which entail huge capital investments and need elaborate distribution networks, biogas plants are decentralized systems which can be installed even in remote areas with very low investments. Thus, biogas technology can also create employment opportunities in the rural areas.

Biogas plant models

A typical biogas plant has the following components:

- a *digester* in which the organic matter mixed with water is fermented;
- an *inlet tank* used to mix the feed and let it into the digester;
- a *gas holder* in which the generated gas is collected;
- an *outlet tank* to remove the spent slurry; and
- *distribution pipeline(s)* to take the gas into the kitchen.

The approved designs of biogas plants under NPBD are:

- *Floating metal drum type*, popularly called the KVIC (Khadi and Village Industries Commission) model, and
- *Fixed masonry dome type*, commonly known as Deenbhandhu model.

The floating drum design

This is an old Indian design with a mild-steel, ferro-cement or fibre-glass drum which floats along a central guide frame and acts as a storage reservoir for the biogas produce. (Figure 2a).

The fixed dome design

This design is of Chinese origin and has a dome structure made of cement and brick. It is a low-cost alternative to the floating drum, but requires high masonry skills and is prone to cracks and gas leakages. (Figure 2b).

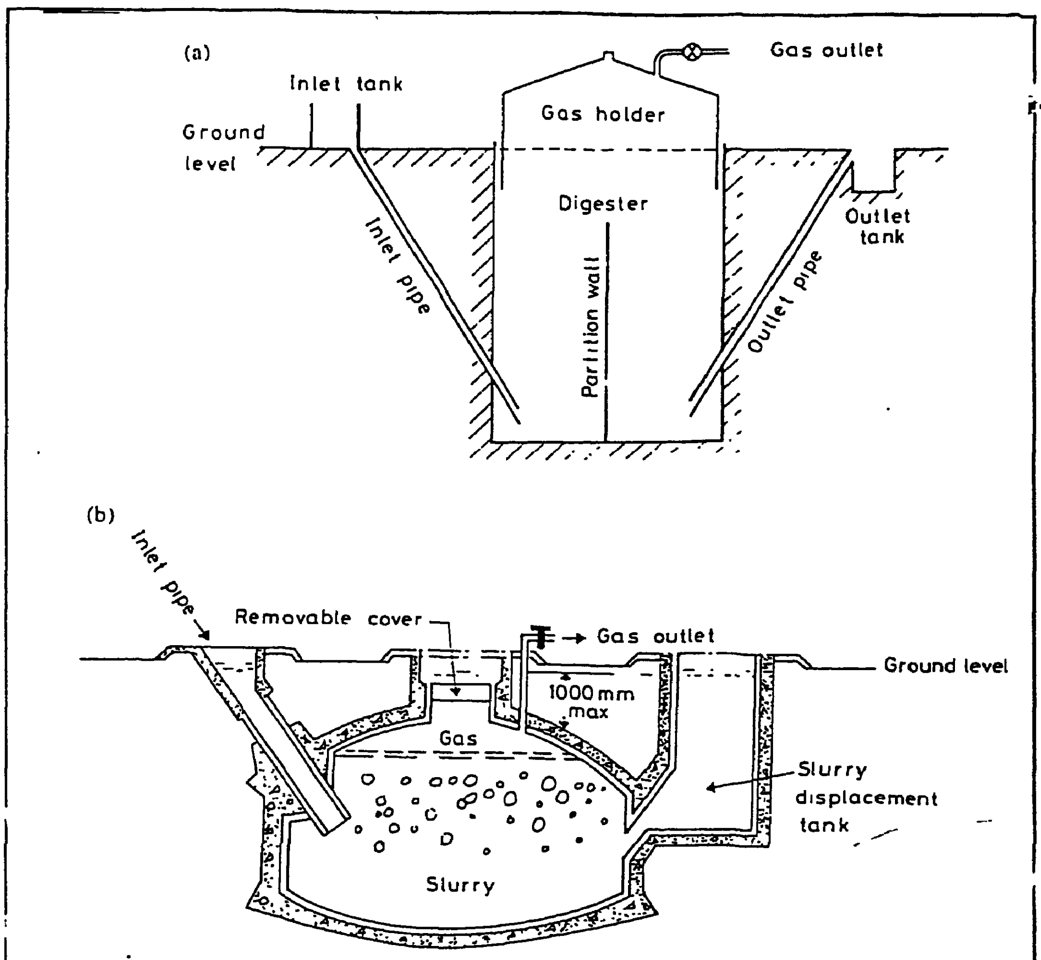


Figure 2 Design of fixed-dome and floating drum biogas plants. (a) Floating gas-holder drum design. the conventional Indian design; (b) fixed gas-storage dome design: low-cost modified Chinese design.

The features of fixed- and floating-drum biogas designs in India are given in table 2.

Table 2. Features of fixed- and floating-drum biogas

Fixed dome	Floating drum
Digester and gas holder, masonry or concrete structure	Digester and gas holder, masonry or mild steel or fibre glass structure
Requires high masonry skills	Low masonry or fabricating skills
Low reliability due to high construction failure	High reliability, gas holder prefabricated
Variable gas pressure	Constant gas pressure
Digester could be inside the ground	Requires space above ground for three tanks; inlet, digester, outlet
Low cost (2 m³ = Rs 500)	High cost of plant due to gas holder (cost for 2 m³ = Rs 8000)

According to the capacity of the biogas plants, these can be categorised as **family biogas plants** and **community biogas plants.**

Family biogas plants come in different sizes depending on the availability of dung and the quantity of biogas required for cooking. The average size of the family is 5–6 persons, and thus a biogas plant of capacity 2–4 m^3 is adequate. The biogas requirement for cooking two meals is estimated to be 150 l/capita/day (about 1200 litres for a family). If the making of tea and snacks is included, about 200 litres of biogas is required/capita/day.

Variants of KVIC model, such as digester made of ferro-cement and gas holder made of fibre glass reinforced plastic, are also being promoted. A bag type portable digester made of rubberised nylon fabric, developed by a private firm namely. M/s. Swastik Rubber Products Ltd., Pune is also being promoted.

The Deenbandhu model

Deenbandhu model was developed in 1984, by Action for Food production (AFPRO), a voluntary organisation based in New Delhi. Deenbandhu has probably been the most significant development in the entire biogas programme of India as it reduced the cost of the plant to almost half that of KVIC model, and brought biogas technology within the reach of even the poorer sections of the population. The cost reduction has been achieved by minimizing the surface area through joining the segments of two spheres of different diameters at their bases. This structure acts as digester as well as gas storage chamber. Once the gas collects in the digester, pressure is exerted on the slurry which is pushed into a displacement chamber. Once the gas is drawn out from the outlet, the slurry again enters

the digester. The brick masonry dome, which is fixed, requires skilled workmanship and quality material to ensure no leakages. The material requirements for the plant are given in table 3.

Table 3. Material requirements for Deenbandhu biogas plant

Plant	2 m^3	3 m^3	4 m^3
Bricks (class I) (nos)	1000	1300	1600
Cement (bags)	14	16	22
Stone chips (cu ft)	40	50	60
Sand (cu ft)	40	50	60
Coarse sand (cu ft)	40	50	60
GI pipe ½" diameter with sockets (inch)	7	7	7
AC pipe 6" diameter (ft)	6	6	6
Iron bars (6 mm diameter) for outlet tank cover (kg)	7	10	12
Paint (liter)	1	1.5	2

Cost

The cost of a biogas plants depends on its size and the design. The subsidy component accounts for over 63 per cent in the north-east and hilly forest districts of Uttar Pradesh state and to about 28 per cent of the total cost of a 2 m^3 KVIC design in the plains of India. The rationale for higher subsidies in forest districts is the assumption that their dissemination will reduce the pressure on forests and decrease deforestation. Households wishing to build a biogas plant can obtain a commercial bank loan at concessional rates of interest (at 11.5–13.5 per cent compared to 17.5 per cent interest on normal commercial loans) and also claim the subsidy component. The cost of Deenbandhu biogas plant is given in table 4.

Table 4. Average cost of a Deenbandhu plant (Rs)

Plant capacity	40 days HRT	55 days HRT
1 m^3	5800	8100
2 m^3	6800	9400
3 m^3	8200	11500
4 m^3	10500	14800

Reasons for failure of biogas plants

Both structural and operational reasons seem to contribute to the failure of biogas plants.

Feasibility of design

Decisions about acquiring a biogas plant and its size depend mainly on the number of cattle owned and the availability of dung. As an extreme case, in Maharashtra 65 per cent of the biogas plants built were not feasible, indicating that families did not have adequate information regarding the dung resource requirement.

Structural defects

The common defects for failure of fixed-dome biogas plants are: damage to the foundation and cracks in the dome and digester wall. The major reasons for failure of floating-drum biogas plants are: corrosion of the gas holder and collapse of the central guide frame.

Problem with the fixed-dome design arise out of the lack of skills to build leak-proof domes or strong walls and foundations. In the case of the floating-drum design, lack of funds to replace the steel drum or absence of infrastructure to repair the drum contribute to failure.

Operational problems

Among the technical problems, corrosion, leakage and water accumulation in gas pipelines, and defective burners are the dominant reasons. Shortage of dung is the main non-technical reason for failure.

High cost of repair

Damage to the civil structure is a common reason for failure in fixed-dome plants; the cost of repairing a cracked or damaged dome is as high as 30 per cent of the full cost of a biogas plant and repairing the inlet and outlet tank costs 5–10 per cent. Thus even if repair services are available the cost is so high that the owner of a biogas plant will hesitate to get it repaired.

Potential

In terms of total dung that is available in the country, the potential of biogas in India is high. The bovine population in India is 26 crore. An adult bovine produces an average of 10 kg of dung per day. Since, grazing is a common practice in India, all the dung produced cannot be collected. If it is assumed that 75% of the dung is collected, nearly 20 lakh tonnes of dung would be available everyday. At 25 kg per one cubic metre, this dung can feed as many as 400 lakh biogas plants of two cubic metre capacity, which can be

considered the ultimate potential for biogas technology. Even this high potential of biogas is based on animal dung only. All organic matter can technically be used to generate methane; if the scientific experiments that are going on in the country under the patronage of MNES to develop alternative feedstocks (such as water hyacinth, kitchen waste, and poultry waste) come to fruition, potential for biogas generation could be virtually unlimited. It can be mentioned in this context that human waste is another excellent source of biogas which would enhance the potential substantially. The barriers to utilising potential of biogas are given in the Annexure.

With such high potential, which can be routed to hitherto unemphasised applications of shaft power and electricity generation, biogas can make a significant contribution to the development of small industries and agriculture, and thus to the overall advancement of the rural areas.

ANNEXURE

Barriers to utilising potential of biogas

Family biogas plants

	Demand-side barriers	Supply-side barriers
Economic barriers	High capital cost/first cost wood stoves	Inadequate funding for biogas at national level for organizing dissemination programmes
	Inadequate credit and high cost of credit, as own capital is scarce even for economic activities	Inadequate subsidy arising out of low funding of the programme, especially for the plains
	No income generation form investment in biogas or cash savings; competition form income-generating activities for investment	Low market volumes for the entrepreneurs and government agencies, thus high cost of organizing biogas programmes; cost per unit of construction and maintenance high
	High repair and maintenance cost and failure demotivate users	
	Easy availability of wood or no cash cost involved in procurement of wood	
Technical barriers	Inadequate dung resource/animal ownership	Inadequate supply of raw materials and absence of quality control. cement, bricks, steel in rural areas
	Problem of initial feeding of plant, which requires large amounts of dung; lack of information on options for initial feeding	Inadequate workshop facilities for fabricating components
	Water scarcity for daily feeding of plant; especially in summer season and drought years in some regions	Inadequate or absence of trained manpower for construction and maintenance
	High rates of failure and frequency of repairs in some regions	Inadequate funding for research and development (R&D)
	No insurance against failures	
Institutional barriers	Complex procedures for obtaining loan, subsidy, and repair service	Absence of NGOs in most areas and limited scope for dissemination through NGOs
	No institutions to provide back-up services for repair and maintenance problems	Absence of private entrepreneurs, no incentives and rigid policies for their participation
	No responsibility for failures leads to lack of faith by the users	Target-oriented nature of programme leads to lack of quality control
	Cooking energy; a problem for women but men take investment decisions	
		Non-availability of women as builders and skilled persons for biogas dissemination programme

Community biogas plants

Demand-side barriers	Supply-side barriers
Fuelwood available at zero cash cost in most locations	
	Limited funding at national level
Large funding required at village level does not enthuse local communities	Inadequate funding for creating support infrastructure for construction and maintenance of CBGs
No incentive for construction and maintenance by NGOs or private entrepreneurs	
Skewed ownership of cattle holdings, thus inequities lead to unwillingness to share benefits equitably	
Inadequate demonstration units to create interest in communities, NGOs, entrepreneurs	No organization at village level to take leadership and accept responsibility
Most rural leaders are men but gathering fuel and cooking is the women's problem	
Social inequities often make sharing of benefits difficult unless good leadership and organization exist	
Inadequate R&D in field; technology package not yet easily available to NGOs or entrepreneurs	Inadequate technical knowledge to handle slurry
Water shortage in some area	Technical skill required for planning and implementation but such personnel not available
Fear of losing dung or nutritive value of dung; unacceptability of slurry due to inadequate information	

Improved Cookstoves

Biomass stoves - a definition

Cooking stoves that burn biomass such as firewood, agricultural waste and dried animal dung are called Biomass stoves. Most commonly these are known as cookstoves, woodburning stoves, woodstoves, and chulhas.

Fundamental phenomenon in cookstoves

A biomass stove consists of a combustion chamber where biomass fuel burns in the presence of air. The hot flue gases transfer heat to the pan and then escape into the ambient atmosphere. In most stoves, air is drawn into the combustion chamber due to buoyancy. After ignition, the flue gases rise vertically upwards due to buoyancy, causing suction of ambient air into the combustion chamber. This air helps sustain the combustion process, which in turn is the source of buoyancy. The combustion process also transfers heat to the stove body, which in turn loses heat to the surroundings.

Components of biomass stove

A biomass stove is made of certain basic components. There are a large number of different types of traditional and improved cookstoves which have been developed as a part of several cookstoves programmes. Improved stoves attain higher efficiency by:

(a) complete combustion of fuel.
(b) maximum transfer of heat of combustion from the flame to the cooking pots, and
(c) minimum loss of heat to the surroundings.

This is achieved by incorporating all or some of the basic components. These components are:

Combustion chamber or firebox

It is the enclosed space in which the solid fuel is burned. The initial combustion takes place in the firebox. To put it simply, the energy required for the stove to operate is released here. Consequently, the highest temperature in a biomass stove occurs in this part. Mostly cookstoves contain only one fire box, but in some cases there may be a second one to burn the gases produced from initial combustion. The efficiency of the stove depends on the efficiency of combustion in the fire box.

Air inlet to the combustion chamber

The air inlet lets the air inside the fire box. The hot gases produced from combustion of fuel in the fire box rise upward. This causes the suction of air from the inlet to the combustion chamber. The size and dimension of the air inlet is crucial for the performance of the combustion chamber. Many improved stoves have air inlets with control for changing the inlet area. The user is thus able to control the burning rate of the fuel and the temperature in the combustion chamber.

Chimney

It is a vertical pipe attached to the stove to carry hot flue gases out of the kitchen. It helps in the removal of combustion products from the kitchen. The chimney makes the fuel burn better. It pulls air into the chulha and takes smoke out of it. This pull of the chimney is called "draft". The flow of air to the fire started by the draft makes the fuel burn better. Draft takes place because the gases heated by the fire become lighter and therefore rise up the chimney. The space left by the rising gases is filled by colder and heavier air coming in through the firebox mouth. The size of the chimney should be chosen in accordance with the size of the chulha: a smaller chulha needs a smaller chimney.

Points to keep in mind:

1. If a wider and taller chimney is used the draft created as a result will be too strong. Consequently, the fuel will get too much air and burn too fast. But the sideways pull of the chimney will take the flames away before they have touched the pot. As a result, a lot of fuel will be wasted as most of the fire heat will go out of the chimney.
2. If a short and narrow chimney is used, it will not pull in enough air. Thus, the fuel will not burn well and more smoke will be produced. Again a lot of fuel will be wasted as the gases from the fuel will not be able to burn. But a diameter of more than 6 inches is not advisable because cold air could flow back down the chimney.

Chimney is not an essential part of biomass stoves. Generally chimney is provided only in fixed stoves. Portable stoves are usually chimney less.

Grate

It is a frame of metal bars or other material on which the fuel is burnt. The use of grate drastically improves the combustion quality and rate, due to free supply of air and contact of air with the fuel. If a grate is used then:

(a) the walls of the combustion chamber must slope towards the grate, and

(b) the area of air passages openings in the grate should be approximately 25 to 30% of the total grate area.

Dampers

A damper is a movable plate covering a flow passage. It regulates the air flow rate and draught in a cookstove. It can be used at the air inlet or the chimney entry. It is made either of metal, clay or stone. If it is made of metal, then it will be too hot to touch during cooking. Hence, it must be provided with a handle of poor conductive material. Dampers have a strong influence on the efficient performance of biomass stoves.

Baffles

Baffles are the projections in the flue passage. They are used to provide a torturous path for the combustion gases thereby increasing the time for which these gases remain inside the stove. This helps in completing combustion and in improving the heat transfer to the pots by redirecting the flow of hot gases around the pot. When baffles are placed at the exit of the fire box, they re direct the flame and the gases back into the surface of the wood, as well as the pot surfaces facing the fire bed, thereby accelerating the cooking process.

Cowl

This is a metal cap attached to the chimney. This prevents rain from entering the chimney. Cowls also improve the chimney draught irrespective of the direction of the wind.

Classification of biomass stoves

Biomass stoves can be classified in several ways based on:
(a) the fuel burnt in the stove,
(b) the material used in the construction of the stove,
(c) fixed and portable (moveable) nature of the stove, and
(d) number of pots or pans the stove can heat at a time (Figure 1).

The classification based on fuels is on the type of fuel it can burn:
(a) stoves for woody biomass-wood, animal dung and agricultural waste;
(b) stoves for powdery biomass-sawdust, ricehusk etc; and
(c) charcoal stoves-suitable for fuels that burn without a flame such as charcoal and coke.

Material used for construction of stoves are masonry or unfired clay (also known as mudstoves), fired clay and metallic sheets or cast iron. Mudstoves are usually constructed in situ and are called fixed stoves. They are heavy and absorb a lot of thermal energy of combustion of the fuel, owing to their large thermal mass. They also remain hot for long durations after cooking. Ceramic and metallic stoves are light weight and portable. They

have considerably lower thermal mass and therefore store less thermal energy in their bodies. Stoves can be single or multi pot types. In multi pot stoves, usually, passages are provided for the hot flue combustion gases to pass under all pots. Single-, two-, and three-pot designs are common in both traditional and improved stoves. Most multi pot stoves are fixed, but portable multipot stoves of ceramic or metal are also there.

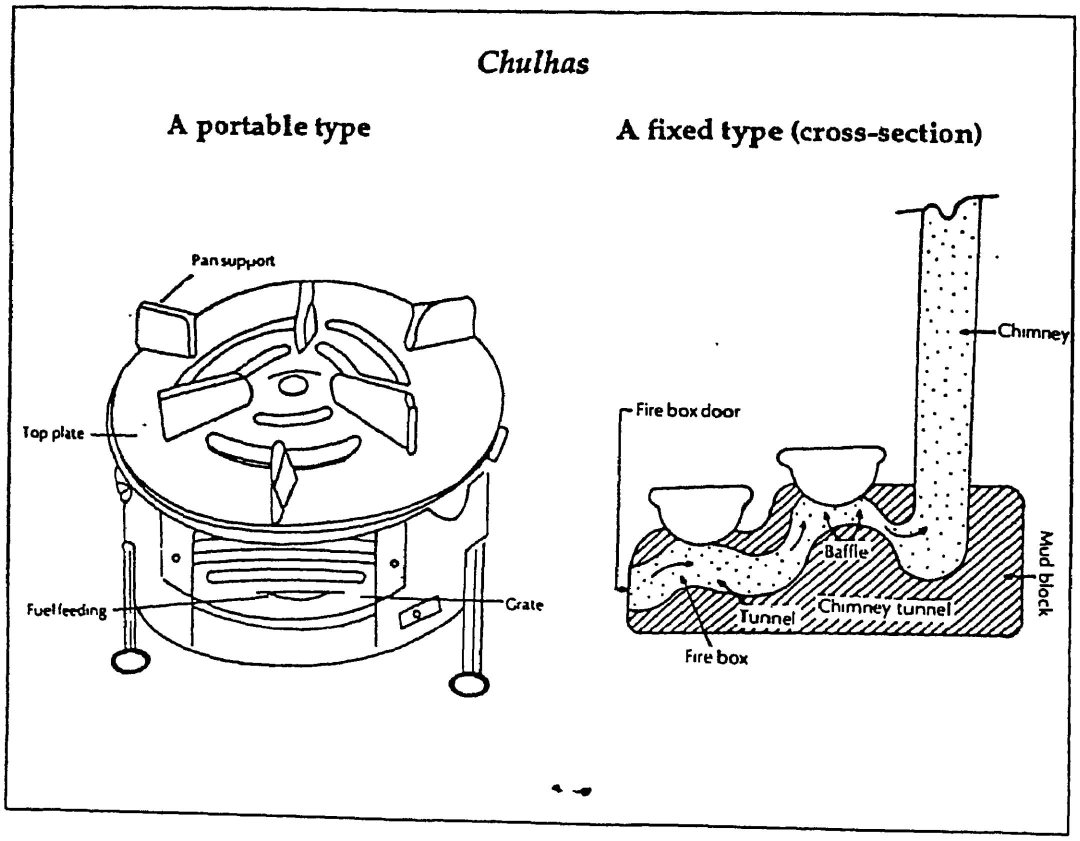


Figure 1. Improved cookstoves

Development of improved cookstoves

The development of improved cookstoves in India dates back to 1947, when the Magan chulha was developed. The HERL chulha and the Junagadh chulha followed in the 1950s. Since then numerous models have come up, both portable and fixed types, developed by various research centers, universities and technical institutes. NPIC has provision for installation of fixed or portable chulhas depending on the requirements of the beneficiaries. While the fixed models are constructed in the household kitchens using locally available materials by SEWs, the portable chulhas are manufactured by small scale industries and are distributed to the beneficiaries. Improved cookstoves are available for domestic, community, institutional and commercial applications.

Types of ICs

- mud built, fixed chulha with or without chimney,
- mud clad, pottery lined fixed chulha with or without chimney,
- portable metallic chulha without chimney,
- portable metal clad, ceramic lined chulha without chimney, and
- portable chulha with a separate hood chimney system.

Though several old models are also in use in the field, however these have been superseded by newer models that are more convenient to build and operate, more energy efficient and with better/more fuel flexibility. The two features of the old models that the users have altogether rejected are the a) tunnel baffle, and b) door damper. These have been done away with in the newer models. A list of the cookstove models, features, approximate costs and the name of the organisation that has developed them is given in Annexure. These models have been approved under NPIC and represent the recent technical development in cookstove design.

Potential

A saving of about 120 lakh tonnes of firewood equivalent valued at Rs 480 crores per annum is estimated by the use of cookstoves. The estimated requirement of improved stoves in India is 1200 lakhs. Assuming a stove dissemination rate of 2 million/yr, another 53 years will be needed to provide stoves to all the remaining households. Further, a majority of stoves built are mudstoves which have a life of 5 to 8 years, if properly maintained. Thus, the stoves installed will also have to be replaced and, at the current rate of provision, all rural households man never obtain an improved stove.

Annexure

Models of Improved Cookstoves

Model name and year developed	Organisation	Features	Cost (Rs)	States
Abhinav/Jetan,1987	Technical Back up Unit, Energy Research center, Punjab University, Chandigarh-160014	*fixed, two pot, mud stove with chimney, damper less,* fuel flexibility	55-72	Haryana, Uttar Pradesh, Delhi, Rajasthan and Madhya Pradesh
Akash, 1991	Technical Back up Unit, Energy Research center, Punjab University, Chandigarh-160014	fixed, two pot mud stove, with chimney, multi fuel, suitable for large families	55-80	Haryana, Himachal Pradesh and Rajasthan
Alok, 1989	Technical Back up Unit, Center for Rural development and Appropriate Technology, IIT, New Delhi-110016	fixed two pot mud stove with chimney, interconnecting tunnels lined with fired clay tubes	75-100	Uttar Pradesh, Haryana and Punjab
Aravali U, 1989	Renewable Energy center, College of Technology and Agriculture Engineering, Rajasthan Agricultural University, Udaipur	fixed two pot mudstove with chimney, multi fuel	55-80	Rajasthan, Andhra Pradesh and Uttar Pradesh
Astra, 1985	TBU, Karnataka State Council for Science and Technology, IIS, Bangalore.	2 or 3 pot cement-brick stove with chimney, multi vessel, multi fuel	55-102	Southern India
Bhagyalaxmi, 1991	TBU, Center for Application of Science and Technology for rural Development, Indian Institute of Education, Pune	two pot, non-chimney mud stove, multi fuel	40	Maharashtra, Goa and Karnataka
Dengli 1991	TBU, CRDAT, IIT New Delhi	single pot mud stove without chimney, combustion chamber of a perforated pottery liner, multi-vessel, multi-*fuel*	27	Rajasthan, Haryana, Delhi, Uttar Pradesh, and Madhya Pradesh
Doachhi 1989	TBU, Department of Mechanical engineering, Bihar College of Engineering, Patna	two pot hole, pottery liner, cast iron grate, fire box between two pot hole, multi-vessel, multi-fuel, suitable for boiling and steaming	70-87	Bihar, and Uttar Pradesh
Gaurav 1989	TBU, ERC, Punjab University, Chandigarh	three pot, pottery lined mud stove, multi-fuel, metal rod grate, pot hole arrange in triangular shape	75-110	Punjab, Chandigarh, Haryana
Grihlakshmi 1990	TBU, CASTFORD, Indian Institute of Education, Pune	single mud stove without chimney, suitable for baking, metal rod grate, slotted cast iron top plate for converging the flame	32-42	Maharasthra, Goa, Karnataka
Harsha 1990	TBU, Regional Research Laboratory, Bhuvaneshwar	potable, metallic, single pot stove without chimney, multi-fuel, corrugated grate design with scrapper	144	Orissa, Himachal Pradesh, Punjab, Uttar Pradesh, Maharashtra

Model name and year developed	Organisation	Features	Cost (Rs)	States
Janata 1991	TBU, Central Glass and Ceramic Research Institute, Khurja, UP	single pot, portable, metal clad, ceramic lined stove without chimney, highest reported thermal efficiency in India, special ceramic liner design , steep secondary air hole around the ceramic wall, considerable strength, low-cost	100	
Kesari-200 1988	TBU, CRDAT, IIT New Delhi	two pot mud stove with chimney, suitable for community cooking, fuel wood, controlled design of connecting tunnel, baffle at the center of second pot hole	100 + cost of bricks	
Lakshmi 1986	TBU, CASTFORD, Indian Institute of Education, Pune	two pot mud stove with chimney, used for baking boiling and steaming, multi-fuel, ready made parts available	70-87	Maharashtra, Goa, Madras
Mamta 1989	TBU, Department of Home science M S University , Baroda	two pot mud stove with chimney, pottery liners for combustion chambers and tunnels, suitable for baking, multi-vessel, multi-fuel	55-72	Gujarat, Karnataka
Meghalaya 1987	Nodal agency of Meghalaya and TBU, CRDT, IIT New Delhi	two pot mud stove with chimney, suitable for smoking for fish and meat, smoking chamber connecting to the tunnel (after the second pot hole), hooks for hanging fish/meat in the chamber, fuelwood	93-110	North-eastern States
Mohani-U 1990	TBU, ERC, Punjab University , Chandigarh	single pot, pottery lined mud stove with chimney, multi-fuel, multi-vessel,	70-82	Haryana, Punjab, Rajasthan
Nav Jyoti 1991	TBU, CRDAT, IIT New Delhi	single pot portable metal stove without chimney, low-density biomass fuels and briquettes, improved over the traditional model called angeethi	75-158	Maharashtra, Gujarat, Himachal Pradesh
Parishad-21 1986	Kerala Sasthra Shitya Parishad, Trivandrum and TBU, Department of Mechanical Engineering, College of Engineering , Trivandrum	three pot mud brick stove with chimney, coconut fronds and fuelwood and agri-residues, two pottery lined combustion chambers, pottery tunnels, metal grates and asbestos chimney pipe, suitable for cooking in standing position	95	Kerala
Pawan-II 1988	TBU, CRADAT, IIT, New Delhi	single pot pottery lined mud stove with chimney, multi-fuel, multi-vessel	70-82	Uttar Pradesh, Delhi, Harayana, Rajasthan
Priagni 1983	Central power Research Institute, Bangalore	most popular portable metallic non-chimney wood stove available in four sizes, suitable for fuelwood and twigs, combustion chamber provided with aluminum lining	105-188	

Model name and year developed	Organisation	Features	Cost (Rs)	States
Priya 1989	TBU, Department of Home science MS University, Baroda	two pot pottery lined mud stove with chimney suitable for baking of local dishes, multi-fuel, first pot hole with step rim construction	55-80	Gujarat
Sohini 1987	TBU, ERC, Punjab University, Chandigarh	single pot mud stove with chimney with grate, used for slow heating of milk and animal feed, suitable for traditional cooking, stove tunnels has elliptical shape in the cross section for better fuel efficiency, multi-fuel	55-70	Haryana, Uttar Pradesh, Delhi, Punjab, Rajasthan and Himachal Pradesh
Sudha 1992	TBU, ERC, Punjab University, Chandigarh	low cost single pot pottery stove without chimney, multi-fuel can be used as fixed or portable stove, double wall fired clay grate for complete combustion	30-40	
Sugam-II 1998	TBU, CRDAT, IIT New Delhi	fixed two pot mud stove with chimney, multi-vessel, multi-fuel, pottery liner for combustion chamber, cast iron split grate asbestos chimney	70-80	Delhi, Uttar Pradesh, Harayana
Sugam Seva 1988	TBU, CRDAT, IIT New Delhi	two pot mud stove, suitable for agri-residues and dung cake, combustion chamber constructed below ground level to facilitate feeding, no grate, multi-vessel	55-72	West Bengal, Bihar, Orissa
Sukhad 1988	TBU, College of Technology and Agricultural Engineering, Rajasthan Agricultural University, Udaipur	two pot mud stove, multi-fuel, accommodate large size vessels, pottery liner, cast iron grate, metallic moulds available	55-72	Rajasthan, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Madhya Pradesh, Bihar
Surbhi-T 1987	TBU, ERC, Punjab University, Chandigarh	three pot mud stove with chimney arranged in T shape, suitable for water heating, multi-fuels, multi-vessels	55-80	Himachal Pradesh
Uday 1989	TBU, College of Technology and Agricultural Engineering, Rajasthan Agricultural University, Udaipur	single pot mud stove with chimney without grate, bent flue pipe of asbestos cement that diverts gasses downward for better fuel efficiency, D-form baffle in tunnel, suitable for boiled and steam dishes	55-67	Rajasthan, Madhya Pradesh, Uttar Pradesh, Andhra Pradesh

Biomass gasification

Introduction

Biomass materials such as firewood and agro-residue essentially contain carbon, hydrogen, and oxygen along with moisture and ash. Direct combustion is generally inefficient, smoky and has a low degree of control. Further utilization of biomass as a source of energy for normal purpose like shaft power generation or electricity generation calls for its conversion to a more convenient form, liquid or gaseous, before it could be used in existing mechanical devices. Biomass can be converted into gaseous form through two processes: (a) biological conversion processes, and (b) thermo-chemical conversion processes. Anaerobic fermentation of cellulosic materials like animal wastes, plant materials etc. to produce biogas is an example of biological conversion of biomass. The thermo-chemical conversion includes destructive distillation, pyrolysis, gasification etc. The most important one in the present context is the gasification process.

Biomass gassification

Under controlled conditions of low oxygen supply and high temperatures, most biomass material can be converted into a gaseous fuel known as 'producer gas'. Producer gas consists of carbon monoxide, hydrogen, methane and nitrogen. The solid biomass is subjected to a series of thermo-chemical process like drying, pyrolysis, oxidation and reduction in a gasifier to get producer gas. The calorific value of this gas is about 1000-1200 kcal/Nm^3.

This gas can be used for generation of motive power either in dual fuel engines or in ordinary diesel engines with some modifications. Engines operating on a spark ignition system e.g. a petrol engine can be made to run entirely on producer gas, whereas those using compression ignition systems e.g. a diesel engine can be made to operate with about 70-80% fuel replacement by the gas. The gas can also be used for a variety of thermal applications including cooking, crop drying, process heat for different industries, vapour absorption cooling etc. Thus, in all its applications, whether thermal or power generation, biomass gasification result in significant environmental benefit by partially or completely replacing the use of commercial energy sources.

Type of gasifiers

There are two types of gasifiers:

(a) *Fixed bed gasifiers*. These are the simplest type of gasifiers and are used for all small-scale applications. A fixed bed gasifier has a bed of solid fuel particles

through which air or gas passes either up or down. Depending on the movement of gases relative to the fuel bed, the fixed bed gasifier can be classified as: (i) downdraft (Figure 1), (ii) updraft (Figure 2), and (iii) crossdraft. The downdraft gasifier gives a clean gas having low tar content and is generally used for power generation applications. The updraft gasifier is mainly used for thermal applications.

(b) *Advanced gasifiers*. These are fluidised bed gasifiers and suspended particle gasifiers. These are still under development.

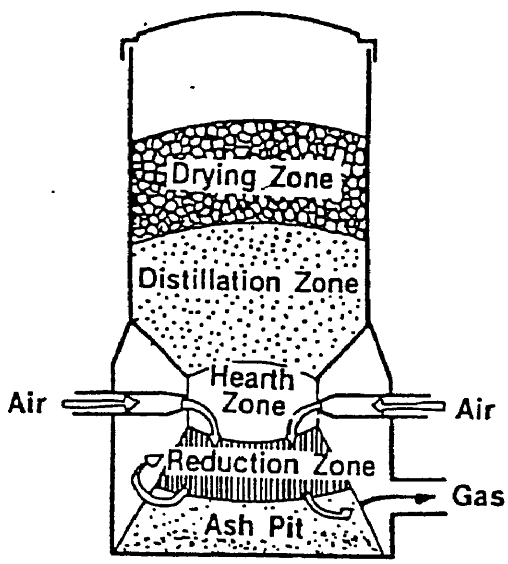


Figure 1. Downdraft gasifier

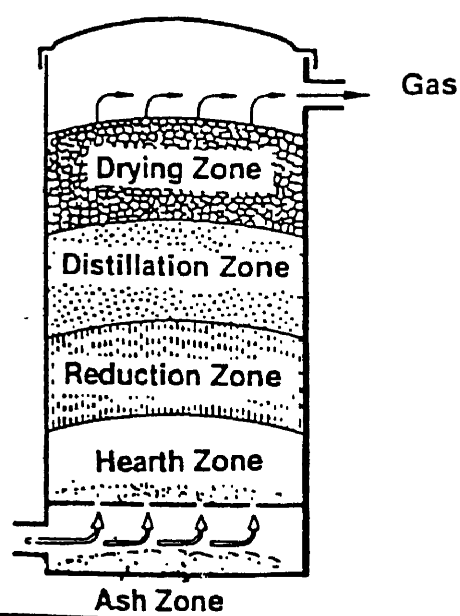


Figure 2. Updraft gasifier

Potential of biomass gasification in India

In India, organic matter derived directly or indirectly from forestry and agricultural or livestock activities, namely wood, crop residues, animal wastes, etc. is the main source of biomass. In the recent past, an increased level of activities in the agriculture sector, unabated rise in human and livestock population, and rapid rate of urbanization and industrialization have resulted in large-scale production of waste materials that have a high cellulose content and, hence, are a potentially rich source of energy (with appropriate conversions).

Several renewable resources are abundantly available at agro-processing centres. Such resources include rice husk, bagasse, molasses, coconut shell, groundnut shell, maize cobs, potato waste and coffee waste. Likewise, organic residues such as rice straw, wheat straw, cotton sticks, and jute sticks are also available on farms. These resources may be used as fuel and, in fact, may be brought into use for several other applications as well.

The various biomass fuels that can be used in the gasifiers are:

- wood chips from logs and slabs:
- wood wastes from timber harvesting, saw mill operations etc.;
- field crop residues like wheat straw, cotton stalks, maize cobs, bagasse, corn cobs, groundnut shells, coconut shells, rice husk, jute stick, etc.;
- industrial waste like tobacco waste, ayurvedic herbal waste, coffee husk, etc.; and
- cowdung cakes

The above list is not exhaustive and in fact any carbonaceous matter can be gasified in principle. However, it is found that fuels with a high ash content are not easily gasified and pose a major technical challenge at present. Also, some sort of pre-treatment like drying, densification (briquetting) etc. is usually needed before use in the gasifier.

Agricultural commodities may be processed at the household level, in small processing units, or in modern mills. Therefore, the quantity and quality of residues available at each site depend not only upon the specific agro-climatic conditions of a region, but also on the scale and efficiency of the processing unit. The agriculture based biomass availability data (based on normative values of crop yield ratios) are presented in Table 1.

Table 1. Agriculture based biomass availability potential for 1990-91

Biomass	Area (mha)	Production of crop (mt)	Crop residue (mt)
Rice husk	42.6	74.6	37.3
Wheat straw	24.0	54.5	72.5
Maize cobs	6.0	9.1	2.7
Millet straw			
Pearl millet	10.4	6.9	11.5
Finger millet	2.2	2.3	11.2
Small millet	2.5	1.2	3.1
Sugarcane bagasse	3.7	240.3	79.3
Coconut	1.5	9.7*	
Shell			1.3
Fibre			1.6
Pith			2.5
Groundnut shell	8.3	7.6	2.5
Cotton stalks	7.4	9.8**	22.2
Jute sticks	0.8	7.8***	2.3

*Production in million nuts
**Production in thousand bales of 170 kg each
***Production in thousand bales of 180 kg each

Considering the abundant availability of biomass residues in India, there exists tremendous potential of biomass gasifier based systems both for power generation as well as for thermal applications. Several studies have been undertaken in recent years to estimate the potential for biomass utilization, in general, and biomass gasification, in particular. It has been calculated that, even after taking into account the demand for fodder etc., the biomass available in the country (excluding animal residues) can optimistically support electrical power plants aggregating to a total of 17,000 MW. Due to accelerated activities in agricultural sectors and agro processing industries the explorable potential is much higher. Recent estimates are as high as 50,000 MW. Sugar industry alone is capable of producing over 3,000 MW of surplus power through bagasse based cogeneration systems.

Important areas of application

Some of the important areas for biomass gasifier based application in India are listed below:

(a) Power generation: (i) Wide range of outputs - from 3 kWe to 500 kWe (or more) using diesel engine on dual fuel mode or SI engine on gas mode. (ii) Grid

connected or stand alone application possible with on-line change over facility. Coupled to the large energy plantations on wasteland or industries producing huge quantities of biomass waste (e.g. coffee, cashew, jute processing industries and sugar mills), power generation at megawatt level can be undertaken for feeding into the grid.

(b) Irrigation/other mechanical applications: Standard size 5 HP or 10 HP (other rating as per need).

(c) Direct thermal applications: Out put ratings of 15,000 kcal/hr - 1.25 million kcal/hr for wide range of applications in industries, institutions etc., for boilers, kilns, driers, ovens, furnaces, cooking, etc. Flame temperature up to 900 °C can be achieved with excellent control over flame temperature, flame length, etc. The added advantage is convenience and cleanliness of gaseous fuel resulting in elimination of smoke and other health hazards.

(d) Energisation of number of pumpsets through localized gasifier based power generation system. This will also reduce need extending grid lines to remote areas resulting in reduced load on grid and reduced distribution losses. Farmers in the rain fed area are also able to go for multi-cropping pattern.

(e) Cogeneration applications:

   (i) Simultaneous production of charcoal and power wherein energy inefficiencies and air pollution problems of traditional charcoal making are converted to electricity as a by-product.

   (ii) Chilling/cold storage applications wherein both thermal energy (for washing/absorption refrigeration) as well as power could be produced in requisite proportions.

(f) Specialized industrial applications for tea/coffee drying, bakery ovens, brick/lime/pottery kilns, etc. Typical application can be in CO_2 producing industries, where producer gas can provide power and heat for the process at very economic cost and also the final main product, viz. carbon dioxide. This also help in reducing CO_2 emissions and replacing highly polluting charcoal, which is presently used for this purpose.

A line diagram of a gasifier system used for power generation is given in the Annexure.

Benefits

Biomass based systems offer the combined benefits of renewability, decentralization and availability on demand without need for separate storage.

Renewability

With readily available conversion technologies (such as gasification): biomass, a renewable source of energy, can indeed provide all forms of energy i.e. electricity, fuel, heat, etc. in an effective and efficient manner replacing use of conventional commercial fuels, partially or completely.

Environmental benefits

Biomass gasification offers significant abatement of CO_2 and other emissions by replacing use of conventional fossil fuels. Also, many agro-processing industry, e.g. cigarette factories, cashew processing units, ayurvedic medicine factories, rice mills etc., produces huge quantities of biomass waste. These are currently being disposed off either in river or in open space causing lot of environmental pollution. Disposal and treatment of waste disposed, cost lot of money and energy. Gasifier application utilizing these available biomass waste not only saves fuel but also prevents environmental degradation.

Decentralization

Decentralized and appropriate renewable energy technologies for a vast and diverse country like India can go a long way in alleviating the current energy crisis. The major advantages of biomass gasifier based power plants are its low capital investment required (Rs. 10,000-15,000 per kW as against Rs. 30,000-30,000 per kW required for thermal power plant) and low gestation period. This will enable the faster addition in installation power plant capacity with low investment in order to meet the increasing demand and supply gap. Thermal gasifier application in remote areas will lead to reduction in demand for conventional fossil fuels and their transportation cost.

Gasifier programme in India

The gasifier programme in India was launched in 1986 by MNES. The programme was based on 3.7 kW wood-based gasifier system for irrigation purpose. The aim was to provide insurance against reduced diesel availability for millions of diesel pumpsets in the country. Presently, over 1000 such units have been installed with the total installed capacity of about 8 MW. Diesel replacement of 40%, on an average, has been reported with the use of gasifier systems. Use of gasifier system for village electrification, flour grinding and drinking water pumping has been demonstrated at least three sites: Karnataka, UP Hills and Gujarat. The current focus is on development of 20 kW system capable of being the workhorse for rural industrialization with minimum 65% diesel replacement and 2400 hours/year operation and bankable economic parameters of capital and running costs.

This requires not only disciplined operators but also right materials, design and good workmanship.

Role of Government and other institutions in promoting biomass gasification

In India, biomass gasification programme is under the purview of the MNES. In order to address issues relating to technology, performance, life of gasifier and other related aspects, and to promote commercialization of gasifier systems, MNES aims at encouraging manufacturers of gasifiers. The programme is implemented through several state level nodal agencies. Ministry provides funds for cost sharing of the gasifier systems (subsidy) to state nodal agencies, which in turn is distributed to the manufacturers. The nodal agencies are expected to assist in subsidy distribution, and monitor the performance and support given by the manufacturers so that the users can obtain the expected benefits.

After identifying technically feasible projects, manufacturer approaches concerned nodal agencies (along with consent letter from user) on behalf of the user for its registration so as to get subsidy from MNES. The nodal agency registers the consumers on first come first serve basis. These project proposals are then forwarded to MNES for its approval. After MNES sanction, the nodal agency receives funds for disbursement. Nodal agency releases MNES cost sharing amount of the gasifier system on the erection and commissioning of the system by the manufacturer.The fixed cost subsidy provided by MNES on different types and ratings of gasifier systems as given in box.

Action research centres

In 1991–92, MNES created four Action Research Centres (ARCs) with a substantial financial outlay to catalyze and coordinate various research activities. Areas of specialization of various ARCs are:

(a) *Indian Institute of Technology, Delhi.* (i) biomass characterization, and (ii) development of process technology packages.

(b) *Indian Institute of Technology, Bombay.* (i) product development and research, (ii) technology modification, (iii) testing and instrumentation, and (iv) standardization and development of procedures and methods, quality assurance criterion and cost reduction.

(c) *Indian Institute of Science, Bangalore.* (i) basic research in biomass gasification for non woody biomass materials, and (ii) upgrading and upscaling wood based systems.

(d) *Madurai Kamraj University.* (i) Field evaluation and testing, (ii) monitoring revalidation and training, and (iii) development of application packages including implementation.

Water pumping		
5 hp	Rs.	12,500
10 hp	Rs.	17,000
Electrical applications		
3 kW	Rs.	16,500
5 kW	Rs.	28,000
10 kW	Rs.	51,000
20 kW	Rs.	96,000
40 kW	Rs.	1,56,000
100 kW	Rs.	3,15,000
Thermal applications		
7,500 kcal/hr	Rs.	8,000
12,500 kcal/hr	Rs.	14,000
25,000 kcal/hr	Rs.	25,000
50,000 kcal/hr	Rs.	48,000
1,00,000 kcal/hr	Rs.	78,000
2,50,000 kcal/hr	Rs.	1,57,000

Rural electrification

Such projects are implemented in association with Rural Electrification Corporation. State Electricity Board, Department of Rural Development, Forest Department. State Government Nodal Agencies, local bodies like Village Panchayat, NGO's etc. For taking up such a project; preparation of Detailed Project Report (DPR) giving details of power requirement of village, availability of biomass, specifications of gasifier system, estimations of cost for each components, cost economics of power generation, responsibility of each participating agency, etc: is a pre-requisite. For preparation of DPR, MNES provides Rs. 10,000 + Rs. 100 per kW as a financial incentive. After project approval from the ministry, 75% of the total cost of gasifier system is provided to the implementing agency for its

Other institutions

There are various other institutes working on the research and development of biomass gasifier systems. Punjab Agricultural University and Bharthidasan University are working on fluidised bed gasification of rice straw and rice husk. Sardar Patel Renewable Energy Research Institute has developed 20 kW wood gasifier system which is available for commercialization. Also, 3.7 kW charcoal gasifier (IIT Delhi), 15 kW wood/rice husk gasifier (IIT Bombay) are available for commercialization. Nimbakar Agricultural Research Institute is developing a 10-15 kW open top throatless gasifier for gasification of sugarcane leaves. S J College of Engineering, Mysore is working on development of spark ignition engine for producer gas application.

Tata Energy Research Institute (TERI)

TERI started its work on biomass gasification in 1983. The research and development efforts at the Institute are aimed at developing down-draft throatless gasifier system with low specific gasification rate. Emphasis is on multi-fuel capability and end-use flexibility. An integrated biomass gasifier system capable of utilizing several biomass residues as fuel has been developed along with associated cooling and cleaning train, fuel processing

system, and power generating system. All the system components are assembled on the trolley, making the unit an independent source of energy suitable for rural application in remote areas. The system has been tested at village Dhanwas in Haryana State for supplying electricity to the village temple and for producing mustard stalk briquettes. The salient features of the TERI's gasifier system are:

- *Multi-fuel capability.* The system can operate on variety of agro-residues and industrial waste. Various biomass material used so far includes: bajra stalk, mustard stalk, saw dust, coir pith, groundnut shell, tobacco waste (leaf dust, and stem pieces), herbal waste from ayurvedic industry, rice husk, etc.
- *End-use flexibility.* The system can be used both for power generation as well as for thermal application. Thermal applications tested so far includes: burners for cooking, furnace, CO_2 manufacturing industry.
- *Continuous ash removal system*, enabling the system to handle wide range of biomass having high ash content.
- *Effective cleaning cooling system.* Resulting in low tar and dust content in the producer gas. Wet scrubber system along with cooling tower has been developed resulting in low water requirement for gas cooling and cleaning.
- *Low pressure drop* and therefore less maintenance.
- *Facility to operate in both induced draft and forced draft mode.*
- *Oscillating grate, throatless design.* Enables smooth and continuous flow of fuel within the gasifier.

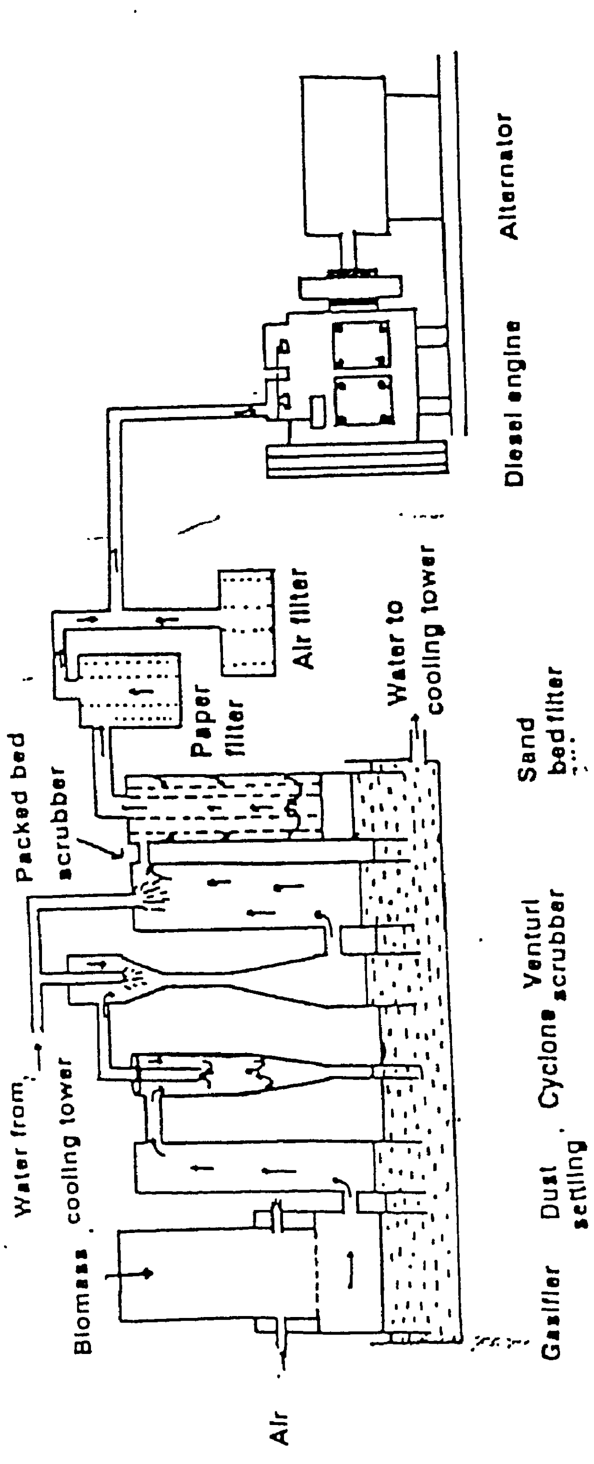


Figure 3. Gasifier arrangment for power generation

Solar thermal energy

Introduction

Energy in the form of heat is one of the main energy requirements in domestic, agricultural, industrial and commercial sectors of our economy. In the domestic sector, thermal energy is needed for cooking, for heating water and for drying purposes. Drying of agricultural products is a pre-requisite for their preservation. Further, the agricultural sector needs thermal energy for growing of plants under controlled environment using green houses. In the industrial sector there is a need for hot water, heated air, gases and liquids and low temperature steam for processing various materials and goods. Also the commercial sector viz., hotels, hospitals, offices, needs thermal energy for variety of applications like hot water, for laundry, steam for sterilization, kitchen washing and bathing and hot air for space heating. Normally, this requirement for both rural areas and urban areas are being met by burning of coal, oil, wood, crop residues and animal dung and use of electricity. Many of these conventional energy sources can be replaced by solar energy.

India is one of the few countries blessed with plenty of sunshine with an annual average insolation varying for 4 to 7 kWh per m^2 per day with 250-300 clear sunny days per year. The entire temperature range required by the applications discussed above can be covered with the available technologies of conversion of solar energy to thermal energy. The available technologies for solar thermal energy can be categorized as follows:

Table 1. Solar thermal technologies

Temperature range	Application
Low grade thermal energy (below 100 °C)	Water heating, air heating, drying, refrigeration, space heating, desalination etc.
Medium grade thermal energy (100 to 300 °C)	cooking, steam generation for industrial applications, drying refrigeration, power generation, water desalination, air heating for industrial applications, pumping etc.
High grade thermal energy (above 300 °C)	Power generation

Solar thermal devices and systems

Various solar thermal devices and systems such as water and air heating systems, timber seasoning kilns, dryers, desalination systems and cookers have been developed for low grade solar thermal energy applications. These technologies are already field proven; they have been commercialized and are finding wide and increasing applications. These are

discussed in more detail below. Some of these have been described in the following sections.

Solar water heater

Solar water heaters are basically of two types: (a) collector coupled to storage tank, and (b) collector-cum-storage system.

Collector coupled to a storage tank type

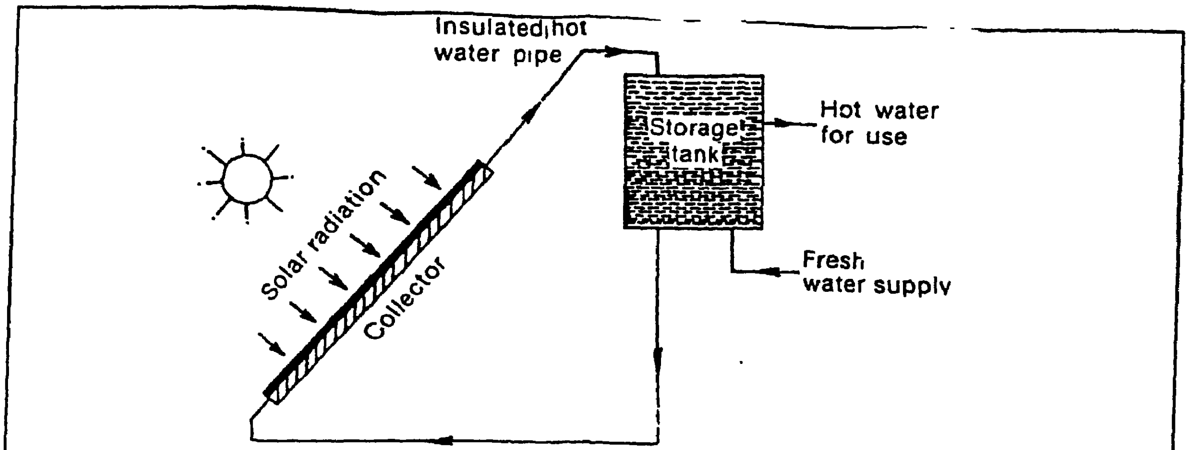
Under this category of solar water heating system there can be two possible ways of extracting heat from the collector: (a) through natural convection, generally known as the thermosyphon effect; and (b) through a forced flow of fluid using an electrically operated pump. The essential components of a Solar Water heating System under this category are:

1. *Collector* consisting of front glazing, metallic absorber, back insulation and collector box;
2. *Insulated storage tank* with or without heat exchanger;
3. *Piping*; and
4. *Controls and pumps.*

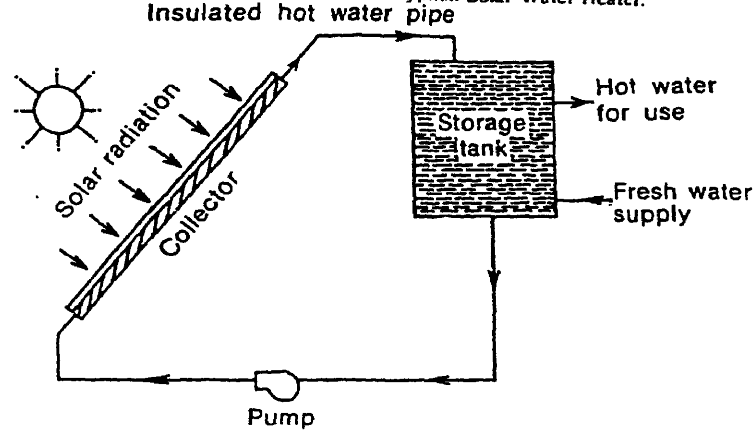
The schematics of a thermosyphon system and forced flow system are given in Figure 1 and 2 respectively. The only additional component in a forced circulation system is a pump, which circulates water in the collector bank. The system may additionally have some control instruments like temperature indicators, differential thermostats, flow meters, etc. These Solar Hot Water systems are usually termed as **open loop systems**. In very cold climates, water alone cannot be circulated through the collector loop. It is necessary to mix anti-freeze materials in the heat extracting fluid circulating through the collector channels. In such systems therefore, a heat exchanger is introduced in the circuit. A heat exchanger is also required if two different types of fluids are used in the collector system and the utility circuit or the quality of water is not suitable due to the presence of impurities.

Collector cum storage type

The collector-cum-storage type water heating system is extremely simple. It consists of essentially three main components: (a) Front Glazing, (b) Absorber Sheet, and (c) Insulated Storage Tank. In such a water heater, sunlight passes through the front glazing and gets absorbed by the absorber which further heats the water. Thus the storage tank acts as a collector and storage for hot water. Solar ponds can also be categorized under this category.



Schematic of a Thermosyphon Solar Water Heater.



Schematic of a Forced Flow Solar Water Heater.

Figure 1 & 2

Sub-components of solar water heater collectors

Collector absorber. The nucleus of a Solar Collector is the black absorber plate which absorbs solar energy and converts it into heat. The thermal radiation absorbing property of black surfaces is utilized in the process of conversion of sun's light to heat. Dull black surfaces have a high absorption coefficient and absorb more than 90% of thermal radiation falling over them. The absorbed radiation is manifested in the form of its raised temperature. The heat is extracted from the absorber plate by allowing any fluid to flow through built-in-channels or tubes welded into it to carry the heat extracting fluid. To minimize the heat losses from the absorber plate it is enclosed in a box covered with transparent glazing from one side, and thermal insulating material from the back and side. A solar absorber should have high thermal conductivity, good heat transfer properties, high solar energy absorbance and low remittance at higher temperatures, it should be non-corrosive and temperature-stable.

Materials for collector absorbers

During the working of a solar water heating system, the ambient temperature may fluctuate between— 30 °C and 50 °C depending on the climatic condition of the place. If the circulation of fluid in the absorber channels/tubes stops due to some reasons, the stagnation temperature may reach as high as 200 °C, and the pressure can be more than 2.5 bar. Not every absorber material can withstand these conditions without damage. Therefore, one has to be careful while selecting the absorber material for solar hot water systems.

Most common absorber materials are: (a) *Copper* is the best material for solar thermal applications. (b) *Aluminum collectors* are also good from the solar energy absorption point of view. However, aluminum is very sensitive to certain impurities present in water and gets corroded. Therefore, it is never used now in direct contact with water. (c) *Combination of copper (riser tubes) and aluminum (absorber sheet)* as absorber is, however, fairly common. Possibility of contact corrosion cannot be ruled out in such case although adverse cases have not been reported. (d) *Stainless steel* is less corrosive. However, the thermal conductivity of stainless steel is low as a result of which the heat extraction is reduced in such collectors.

Plastic absorbers. Offer the advantages of lower cost, ease of fabrication, less weight etc. Some of the materials used for plastic absorbers are EPDM rubber, polypropylene, PVC etc. EPDM absorbers specially have found wide application for heating where temperatures required are not very high such as swimming pools etc.

Collector glazing. A transparent cover over the absorber of the collector has the function of allowing the solar radiation of pass through it and act as an opaque curtain to the radiation emitted by the hot absorber.

Materials for collector glazing

(a) *Tempered glass* is an excellent material for the outermost glazing. The tempering is necessary for the added strength.
(b) *Low iron glass* is recommended for solar applications since the iron in the glass absorbs some solar radiation and reduces the amount reaching the absorber.
(c) *Plastic glazing* are lighter in weight and have better shatter resistance than glass. Due to their ease of fabrication, low conductivity and good transmission of solar radiation, plastics may be preferred instead of glass glazing.

Very often, it becomes necessary to use two or three covers to attain high temperatures. A multiglazing system has a relatively smaller transmittivity for solar

radiation than a single glazing system, but its insulation effect is much more effective. A double glazing is more effective in windy and colder regions.

Collector insulation. Thermal insulations provided in solar collectors help to minimize heat losses from the back and sides of the absorber system. As the collectors may have to operate/remain at temperatures as high as 200 °C the insulation must not deteriorate, expand, or contract at temperatures between—30 °C to 200 °C. It should not attract moisture and should be fire-resistant.

Collector housing. The collector housing is provided to protect the insulation and absorber plate from the environment and also to minimize heat loss. Materials like aluminum, galvanized steel, fibre glass etc. are used for making the collector housing. The Collector Housing should be capable of withstanding weathering effects. It should also withstand loading and handling stresses.

Water storage tank. Depending on whether the system is under the pressure of the city supply or it is non-pressurized, two types of storage tanks are usually recommended for water heating applications.

(a) *Pressurized Water Storage Tank.* The pressurized water tanks are either made from stainless steel or enamelled steel, but rarely with plastic materials. Since cold water after getting heated automatically goes up, the heat exchanger in this system, if required, is placed at the bottom of the tank for a good heat transfer between the exchanger and the fluid in the tank.

(b) *Non-pressurized Water Storage Tanks.* They have the advantage that these can be easily fabricated using materials like fibre glass, plastics, metals, etc. The following heat exchanger designs are possible in these tanks:

1. Collector and storage carry the same (water) heat transfer fluid;
2. Heat exchanger in the collector loop circuit. In such cases the collector loop carries a mixture of water and anti-freeze chemical or some noncorrosive fluid. This fluid heats the water in the storage tank; and
3. In the third design there are two heat exchangers in the tank, one for the collector loop and the other for the load supply.

All these storage tanks are thermally insulated to avoid heat loss. The inner tank should be of a material which does not contaminate the water, is noncorrosive and stable at the temperature of operation. The outer insulation is covered either with a thin metal sheet/foil or cemented to protect it from exposure to rain, dust, and other atmospheric

variations. The thickness of the insulation is decided on the basis of the hot water temperature, the minimum ambient temperature, wind velocity plus thermal resistance of the material. It is desirable that the hot water temperature does not decrease by more than 6-8°C in about 16 hrs time.

Piping. Pipes are used to carry hot and cold fluids from and to the collector. The pipe material should, therefore, be noncorrosive and stable at operating temperatures. It should not contaminate the fluid flowing through the pipes. The pipe diameters in the flow direction should be such that there is a minimum pressure loss.

Solar cookers

Cooking is an important solar thermal application. Solar cookers are perhaps more known to the common public than any other solar device. A solar cooker is like a hot box, in which we can cook our food without any cooking gas or kerosene, electricity, coal or wood. It consists of a rectangular metal enclosure blackened and insulated at the bottom and sides and having two glass covers on the tops. Food to be cooked is kept in shallow closed vessels, blackened on the outer side and kept inside the box. The black surfaces absorb solar radiation and get hot, and this heat is utilized in cooking food. The cooking time is about 45 minutes to 2.5 hours. The cooker works with the solar energy which is freely available.

The solar cooker programme started during 1982-83 with central subsidy of Rs 150 and Rs 15 as a service charge for each cooker. The subsidy was withdrawn by MNES in April 1994. In order to facilitate the rapid development and marketing of different model of cookers, the Ministry is continuing to provide grants to state nodal energy agencies for publicity, demonstration etc. The scheme provides for publicity, quality certification on a cost sharing basis and promotional incentives and awards. There are around 60 manufacturers of solar cooker in the country. A few models of box type solar cookers with different sizes, with and without electricity backup, have appeared in the market.

The number of solar cookers sold in the country during 1995-96 was in excess of 40,000. The cumulative number of cookers disseminated in the country till date is estimated at 4,10,000.The cost of a regular solar cooker varies between Rs 1200 to 2000 each.

Types of solar cookers

Solar cooker can be broadly divided into two categories:

1. Cookers utilizing solar heat with little or no concentration of rays, and

2. Cookers which deflect solar energy from a large surface to a smaller area to produce high temperatures.

The first kind of solar cooker consists of a well insulated box, the inside of which is painted dull black and is covered by one or more transparent covers. The purpose of these transparent covers is to trap heat inside the solar cooker. These covers allow the radiation from the sun to come inside but do not allow the heat from the hot black absorbing plate to come out of the box. Because of this, the temperature of the blackened plate inside the box increases and can heat up the space inside to temperatures up to 140°C which are adequate for cooking.

The second type of solar cooker uses a lens or a reflector suitably designed to concentrate the solar radiation over a small area. This cooker is able to provide higher temperatures on its absorbing surface when suitably designed, but is usually more expensive than the box cooker.

Components

The main part of hot box solar cooker are

1. Outer box
2. Inner cooking box or tray,
3. The double glass lid,
4. Thermal insulator,
5. Mirrors, and
6. Cooking containers.

The outer box. The outer box of a solar cooker may be made of wood, iron sheet or fibre reinforced plastic having suitable dimensions.

The inner box The inner box can be made from galvanized iron, or mild steel or aluminum sheet. All the four sides and the bottom of the inner box which are exposed to the sun are coated with blackboard paint which absorbs solar radiation.

Thermal insulation. The space between the outer box and the inner box is fitted with insulating materials such as glass wool, thermocole etc. This prevents heat losses from the cookers.

The double glass cover. Generally a double glass cover is provided for a solar cooker. These covers have length and breadth slightly greater than the inner box and can be fixed

in a wooden frame maintaining a small spacing between the two glasses. This space contains air which acts as an insulator and prevents heat to escape from inside. The wooden frame is attached to the outer box by means of hinges. A rubber strip is affixed all around on the edges of this frame to prevent any heat leakage.

Mirror. Mirror is used in solar cooker to increase the radiation input on the absorbing surface. Sunlight incident on the mirror gets reflected from it and enters the box after passing through the glass covers. This radiation is in addition to the radiation entering the box directly and helps to quicken the cooking process by raising the inside temperature of the cooker. The use of a mirror can enhance the solar radiation input to the cooker by about 50 per cent.

Cooking containers. The cooking containers (with covers) are generally made of aluminum or stainless steel. The containers are painted dull black on the outer surface so that they also absorb radiation directly.

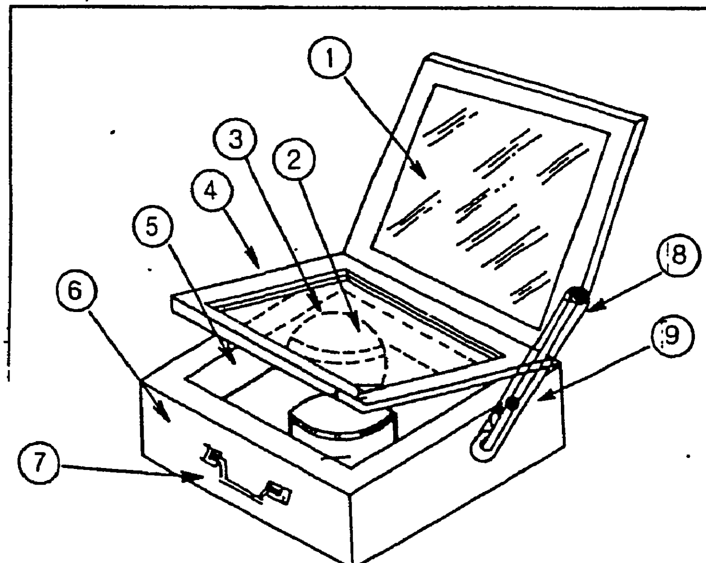


Figure 3. Solar Cooker

Usage of solar cooker

1. Keep the solar cooker in the sun in open space free from any shadow, at least for 15-20 minutes before loading it with cooking pots. This will keep the cooker ready for cooking and reduce the cooking time.
2. Adjust the cooker in such a way that the reflecting mirror faces the sun and the reflected rays fall on the transparent glass lid. Fix the position by tightening the hinges of the mirror in this position.

3. Open the glass lid of the solar cooker, place the cooking pots inside it and close the lid properly.
4. Once the cooking pots have been placed inside the cooker the lid should not be opened.
5. While removing the cooking pots after the food has been cooked, gloves or cloth napkins should be used.
6. The double glass lid should be held carefully while removing the pots.
7. Once the cooking is over, clean the cooker with a dry duster.

Limitations of a solar cooker

(a) It does not work at night.
(b) It does not work as well on a cloudy day. In the early morning, and later in the afternoon, its performance is not so good.
(c) It cannot be used for preparing *rotis*.
(d) It can not be used for frying purposes.

Advantages of the solar cooker

(a) It does not require any fuel except the solar energy.
(b) It is safe.
(c) It does not require constant attention. So it saves the time.
(d) It is simple to operate as solar cooker has a simple design with no moving parts.
(e) No maintenance cost. Only little care is required during handling.
(f) It is pollution free.

Some useful suggestions

1. The level of water along with ingredients should not rise beyond the half- way level in the cooking pots
2. Keep the containers (cooking pots) covered while cooking. In case of baking cake and bread, it is not necessary to cover the containers.
3. Eggs can be boiled in water or baked without water.
4. The food items which required roasting should never be covered. The cooking pots should be greased at the bottom and the food to be cooked smeared with oil.
5. While moving the solar cooker, the cooking pots should be taken out.
6. When not in use, the lid of the solar cooker should remain closed and kept in a sheltered place.

Solar drying

Though it has long been recognized by the world scientific community that controlled drying of agricultural produce is a realistic approach to getting quality foodstuff and avoiding spoilage, this idea has not yet found much application in the Indian agricultural sector. However, now the Indian farmers also have started realizing the need for controlled agricultural drying. Under these circumstances solar energy offers a viable alternative. Drying means removal of moisture from a substance involving simultaneous transfer of heat to the substance, which is known as a unit operation. There are several processes by which heat can be transferred to a substance, like conduction, convection and radiation. There are also processes like respiration and dielectric heating in which the substance is heated internally.

Solar dryers

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Types of solar dryers

Solar dryers can be classified according to the physical principles—radiative and forced convective heat transfer modes—on which their operation is based.

Radiative type solar dryers. These could be fabricated out of readily available materials in rural areas.In radiative type solar dryers solar heat is transmitted by radiation process. The dryers are of cabinet or tent type and may be of different shapes and sizes. These dryers operate by absorbing solar heat through glass or polythene sheet placed over the black absorbing surface. This increases the temperature of air inside the dryer. The moisture produced from the drying material is usually carried out by the exhaust air or condenses on the inside surface of the glass or polythene sheet.

Radiative solar dryers are often used to dry fruits, vegetable, chilies, fishes, etc. The material to be dried is spread thinly in suitable trays which are put inside the cabinet

dryer. The method is very simple and the material is protected against dust, insects, etc. However, except for changing the orientation of the dryer there is no control on the drying process and the drying is also not uniform.

A number of designs of these dryers are now in use in India. In a *tent type dryer* the polythene sheet is supported on bamboo or any other wooden sticks. The solar radiation passing through the polythene sheet is absorbed by the blackened floor of the tent over which the material to be dried is kept. This type of dryer can be made from small to medium size having different drying capacities. The mode of drying may be batchwise or continuous, and depending on the material to be dried the drying time may also vary.

Cabinet type solar dryers. These have also been found to be cost-effective and can well be used in place of the tent type dryer. The cost of construction is a little more, but here glass sheets could be used as the cover which offer longer life.

Passive solar concept

The term "passive solar" encompasses a wide range of strategies in designing and constructing buildings in order to take advantage of the sun's energy and the surrounding environment, thus reducing or eliminating a building's need for conventional energy. Passive solar design uses very few, if any, mechanical devices. The building itself collects, stores and uses solar energy, and is designed to take advantages of site specific features for natural heating, cooling and lighting. By contrast, "active solar" encompasses independent systems including components such as roof collectors, pipes, pumps and tank used to capture the sun's energy for water and space heating needs.

A complete passive solar heating system will include collection of energy, through south-facing glass; storage of energy, through the use of thermal mass, usually in the form of concrete, brick, water or phase change materials; regulation of energy, which may be as simple as providing overhangs, shades or other insulating material for windows, or providing a door to close off a sunspace at night; and distribution of energy, which usually consists of vents, dampers, duct work and small fans.

Types of passive solar heating systems

The three most common passive solar heating systems are

Direct Gain. In this system, the sun shines directly through south-facing windows, into the space to be heated. Thermal storage is provided to absorb and store the energy, and to prevent overheating on sunny days. Good direct gain designs include well conceived shading controls, such as overhangs, blinds, and vegetation to reduce unwanted solar gains.

Suntempering is a relatively low-cost direct gain technique which use a normal amount of windows but simply locates most of them on the south side.

Indirect Gain. This system generally uses a mass wall (Trombe wall) or a water wall directly behind the south-facing glass, separated by a small airspace. The Trombe wall is usually built of concrete, brick or stone, while the water wall is usually constructed of plastic or metal framing. Solar energy strikes the wall and is absorbed and stored for radiation into the living space.

Phase change materials, which release heat as they change form (e.g., from a liquid to a solid state), are also employed in indirect systems. Phase change materials can be incorporated into concrete, brick or stone walls, or even into household furniture. Another popular indirect gain system is a sunspace attached to the south side of a building but separated by common wall. Distribution of sunspace heat to the house is by natural convection of air through open doorways which are then closed at night.

Isolated Gain. Energy is collected and stored in a space "isolated" from the rest of the house, commonly in an attic or greenhouse. The energy is stored in the thermal mass of floors or walls, or in phase-change materials, and redistributed when needed, usually via fans or duct work.

Passive cooling techniques for buildings design are perhaps better labelled as natural cooling mechanisms, in that they require no pumps or fans for their operation. Methods of passive cooling include heat avoidance (e.g., the use of operable shades, overhangs, awnings, and surrounding vegetation); ventilation (using natural air flows and breezes by creating an opening on opposing sides of a house or room, or using the "stack" or "chimney" effect where convective air flow is induced through the use of cupolas, attic vents, belvederes, wind vanes, and wind scoops); evaporative cooling (using roof sprays or ponds, or indoor bodies of water); rotational cooling (using unobstructed horizontal roof or ceiling glazing to take advantage of clear, night time "sky" radiation); thermal mass (interior mass that is ventilated to release accumulated heat); and ground cooling (earth beaming, earth tubes or building underground).

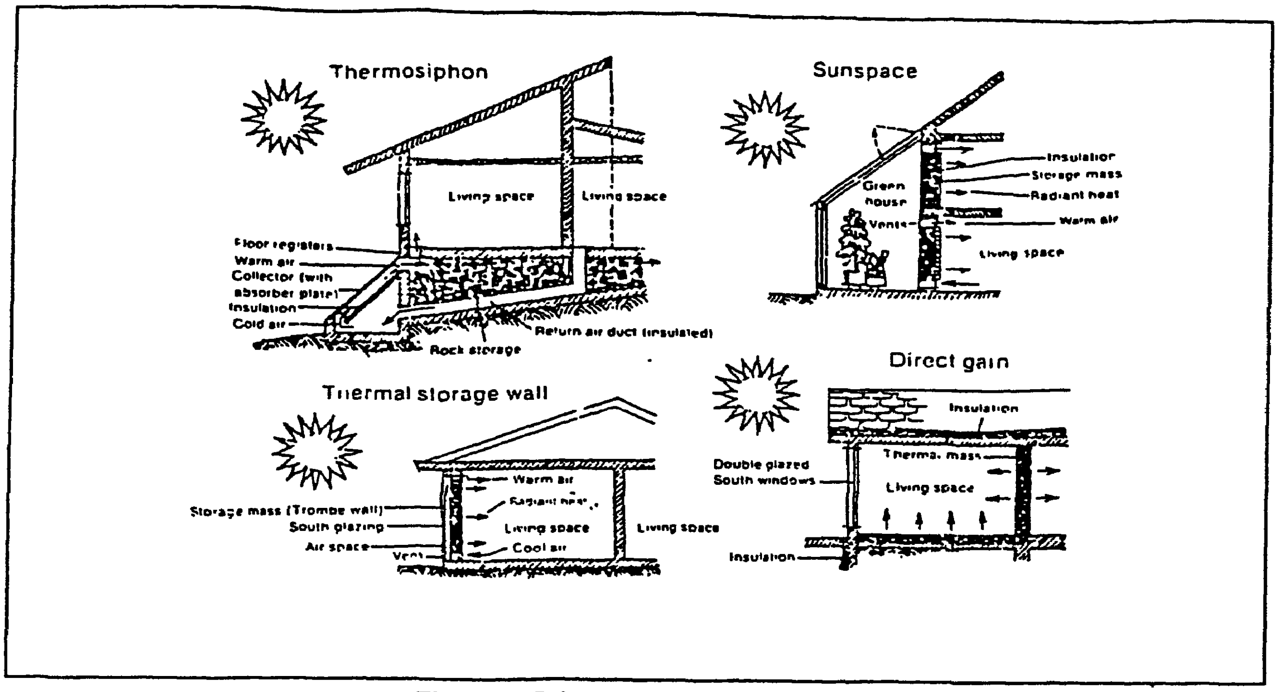


Figure 4. Solar passive heating systems

Day lighting

The use of natural lighting of "daylighting" to reduce a building's energy load is another passive solar design technique. Some of the most common are light shelves; a reflective device, usually located within a window, which reflects and disperses sunlight onto ceilings and walls: a clerestory, an upper extension of a wall pierced with a window to admit light and air: roof monitors, raised sections of a roof with openings, louvers or windows (not parallel to the roof plane) used to admit light and air; and skylight, the familiar glazed roof apertures which are located along the roof plane. Atrium and ordinary windows, if properly designed and located, are other effective daylighting options. Indoor lighting can also be enhanced by combining daylight with artificial lighting control systems.

Solar Photovoltaics

Introduction

"Photovoltaic" refers to the creation of voltage from light and is often abbreviated as just "PV". Solar PV systems directly convert sunlight into useful electricity through semi-conductor electronic process. Solar PV is a convenient technology for generating electricity from the abundantly available sunlight in an environmentally clean and reliable manner. This electricity can be used directly, stored in batteries,or fed into an electric utility's grid system.

Principle of solar cell

Solar cells are essentially thin wafers of Silicon. When light falls on the solar cell it knocks out loose electrons from silicon atoms. Internal electric field pushes these electrons to the front of the cell, from where this electric current flows to the load (see Figure 1).

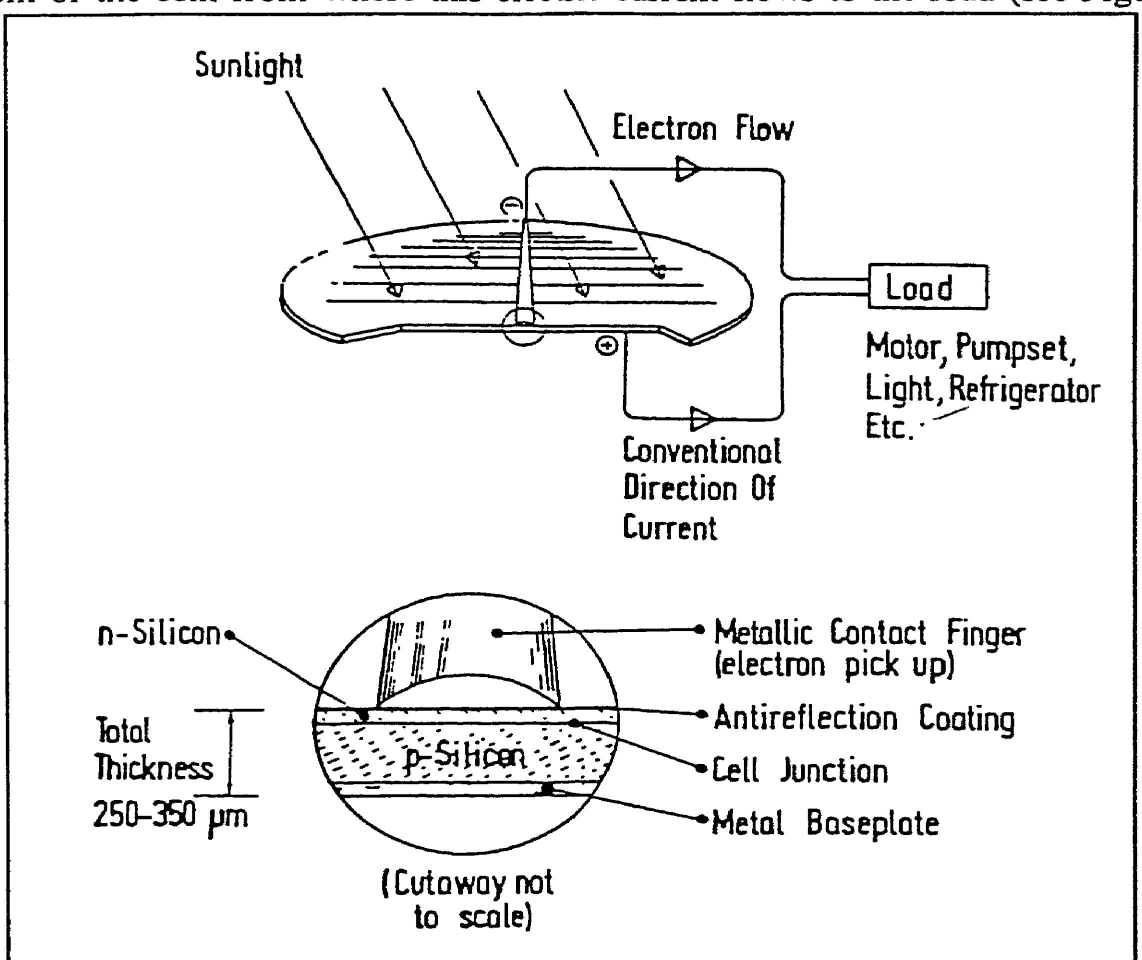


Figure 1. Features of a Mono-Crystalline Silicon Solar Cell

Applications

PV systems are being used to provide power for:

- water pumping,
- house lighting,
- street lighting,
- railway & road traffic signals,
- vaccine refrigeration,
- telecommunication,
- battery charging,
- remote monitoring,
- navigational aids,
- devices installed on space ships and satellites, and
- railway and road traffic signals.

Benefits of solar PV systems

Photovoltaic power systems have numerous advantages including:

- low recurring costs,
- low maintenance costs,
- high reliability of solar panels,
- quiet and clean operation,
- zero fuel usage, and
- modular (sytems can be expanded, if required).

Limitations of solar PV systems

- Requires a high initial cost with savings occurring in later years;
- Not always the best source for meeting large requirements;
- Because the technology is new, repair and maintenance facilities are not readily available in remote locations; and
- Reliability of Balance of System (components other than solar panels e.g battery, charge controllers etc) still requires lot of improvement.

Components of solar PV system

The term "system" is used to describe the complete set of equipment used in converting solar energy to the final requirement e.g. light, pumped water or refrigeration. PV systems are mainly used as stand-alone systems to provide power supply independent of any grid.

A stand-alone system can normally be divided into three parts:

1. *The PV array* (comprising the photovoltaic modules and support structure) which converts solar energy to DC electricity.
2. *The power conditioning equipment* which is optional, but typically includes:
   (a) *Cabling*
   (b) *Controller* which may include battery overcharge protection to prevent gas formation and loss of electrolyte from the battery, an automatic load disconnect facility when battery voltage is low (to prevent damage to the load) and maximum power point tracking (array/load impedance matching).
   (c) *Batteries* these should only be included when storage of electrical energy is required, e.g. for lighting. Essential batteries otherwise should be avoided due to the additional cost and maintenance requirements these impose.
   (d) *Inverter* to convert d.c. to a.c. electricity. As significant energy losses are always incurred in the conversion process it is preferable to use d.c. appliances and avoid the need for an inverter.
3. *Load or end use equipment* e.g. lights, pumps and refrigerators. Most commercial suppliers now prefer to supply complete systems rather than individual components. These are sized for the specific location and energy demand required.

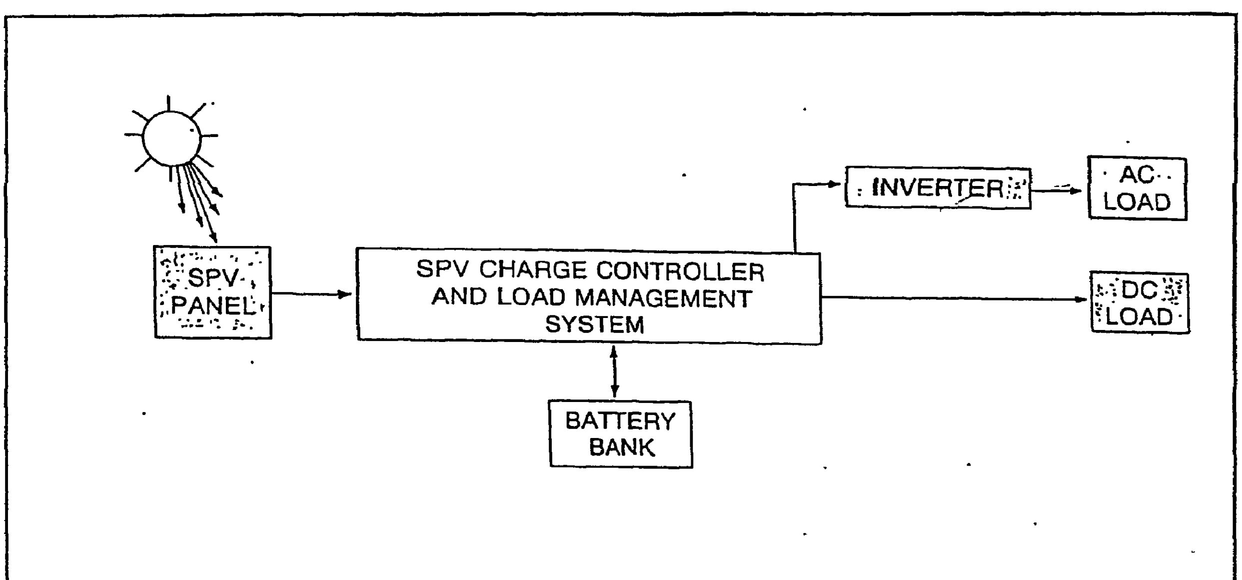


Figure 2. Main components of a SPV system

Rural applications

The majority of the population in our country live in dispersed communities in rural areas. The provision of electricity supply to these areas is difficult and costly. Extension of the conventional grid over difficult terrain is generally not economic for small power loads

and the use of diesel generator sets relies on the availability of fuel supplies and maintenance skills. With abundant sunshine available for almost the whole year round in most parts of the country, the potential of SPV devices is considerably high. The annual average daily global radiation over India is shown in the Annexure. Following products are available in the Indian market which can be used in rural areas:

- solar home systems for individual houses,
- portable solar lights or solar lanterns,
- solar streetlights and battery chargers,
- village based solar power plants,
- solar water pumps for drinking water and minor irrigation,
- Vaccine refrigerators, and
- rural telephones.

The specifications and details of some of the systems disseminated in the country are given below:

Solar home systems

Solar home systems are mainly used for lighting but can also provide electricity for small loads including lights, radio, TV and small appliances. The smallest system of this type consists of a single, roof-mounted module, a simple charge controller, a 12- V battery and fixtures for the loads. Each of the two 9W Compact Flourescent Lamp (CFL)[1] lamps can give light equivalent to 60 W incandescent bulb. Most of the components of the domestic PV system (except for the PV module) can be manufactured or assembled locally. Topping up of distilled water is required in the batteries from time to time, if properly maintained the batteries can last for 5 years or more. More than 32,000 solor home systems have been installed in the country, several of these are working in remote places like Ladakh, Jaisalmer and Sunderbans. The specification of two most common systems are:

Table 1. System configuration.

Specifications	Configuration 1	Configuration 2
SPV panel	30 Wp/35 Wp	60 Wp/ 70 Wp
Lamp No.	2 (9W CFL)	4 (9W CFL)
Battery	12V, 45AH	12V, 60AH
Operation per day	3 hrs	3 hrs
Storage - Number of sun less days	5	3

CFLs work in the same way as standard flourescent tubes (tubelights), the main difference being that CFL tubes are smaller and the tubes are folded over. Due to smaller size they can easily replace incandescent filament bulbs.

Solar lanterns

Most of the solar lanterns available in the market have a 7W CFL that can give light output equivalent to a 40 W incandescent bulb and 12 V, 7AH maintenance and spill proof lead acid battery. The panel is generally of 10 Wp and the lantern can operate for 3 hours daily. The life of the battery is 2-3 years.

SPV water pumping systems

Water pumping with solar energy can be used for providing drinking water to many communities with populations in the range of 1000 to 2000 persons. PV power for water pumping requires no fuel and little maintenance. In this context, the viability of PV in remote or undeveloped locations is superior to fuel-powered alternatives. In regions having shallow water table SPV pump can also be used for minor irrigation.The system sizes available in the Indian market varies from 300 Wp to 2250 Wp. The specification of two pumps available in the Indian market are given in the table below.

Table 2. Pump specifications

	Surface centrifugal pump	Deepwell submersible pump
Type	DC powered monoblock centrifugal pump	AC powered submersible pump
Suction	6-7 m	NA
Total Head	10 m	upto 120 m
SPV panel	900 Wp	1600 Wp
Water discharge	70,000 litres/day	10,000 to 60,000 litres/day depending on the water depth
Application	Minor irrigation (for 2 Hectares)	Drinking water

System sizing

Lighting system sizing

The simplified procedure used for sizing SPV lighting systems are given below. For detailed system design and sizing suppliers of SPV systems should be consulted. The requirements of a lighting system should be appraised in terms of:

- quality and intensity of light required,
- number of lights and their proposed location,
- daily hours of operation,
- the anticipated pattern of use of the lighting system, and
- how requirements may change and future demands.

It is preferable to over-estimate demand but financial resources often prove to be the limiting factor. It is important to look at the overall system and operating procedure when designing the system configuration, e.g.

- If several lights are required in dispersed locations, it may be better to use several small systems rather than one large system,
- portability of lights may be a requirement, and
- automatic switching of outside lighting or timers may be required.

A pro-forma sheet for determine the approximate system sizing required is given in Annexure. An example of system sizing is also shown in the Annexure. If specific component efficiencies are not available battery and regulator efficiencies of 0.8 and 0.9 respectively should be used.

Water pumping system sizing

The output of a solar pumping system is dependent on good system design derived from accurate site and demand data. It is therefore essential that accurate assumptions are made regarding water demand and pattern of use and water availability including well yield and expected drawdown.

Domestic water use per capita tends to vary greatly depending on availability. The long term aim is to provide people with water in sufficient quantities to meet all requirements for drinking, washing and sanitation. Present short term goals aim for a per capita provision of 40 litres per day, thus a village of 500 people has a requirement of 20 cubic metres per day. Most villages have a need for combined domestic and livestock requirement. Irrigation requirements depend upon crop water requirements, effective rainfall, groundwater contributions and efficiency of the distribution and field application system. Irrigation requirements can be determined by consultation with farmers and local experts. Daily water requirements for human and livestock consumption and Irrigation is given in the Annexure.

Assessing water availability

Several water source parameters need to be taken into account and where possible, measured. These are the depth of water source below ground level, the height of the storage tank or water outlet point above ground level and seasonal variations in water level. The draw-down or drop in water level, after pumping has commenced, also needs to be considered for well and borehole supplies. This will depend on the ratio between pumping rate and rate of re fill of the water source. It is useful to present site details to the supplier in the format given in the Annexure.

ANNEXURE

Proforma for PV lighting systems

1. How may and what size of lights are required ? ....

2. How many hours of lighting are required each day? ....

3. Calculate daily energy consumption:

a) .... lamps at .... Watts. for .... hours = ... Wh
b) .... lamps at .... Watts. for .... hours = ... Wh
c) .... lamps at .... Watts. for .... hours = ... Wh

Total daily energy consumption = ... Wh

4. Calculate PV array daily energy load:

$$\text{Array load} = \frac{\text{daily energy consumption}}{\text{battery effic. X charge regulator effic.}}$$

= .... Wh

5. What is the average daily insolation in the least sunny month?

.... kWh/m²

(In India, generally December is the least sunny month, solar radiation during this month is given in the Annexure)

6. Calculate PV array size required from:

$$\text{Array size} = \frac{\text{Array load}}{\text{Insolation x mismatch factor}}$$

(Mismatch factor = 0.85)

= .... Wp

7. Calculate minimum battery capacity

$$\text{Battery Capacity} = \frac{\text{daily energy consumption}}{\text{max. Allowable discharge (\%) x nominal voltage}}$$

= .... Ah

Example of simple system sizing

Requirements: one 8 W lamp plus one 20 W lamp for 4 hours per day

Insolation level: 4 kWh/m^2/day

System nominal voltage: 12V

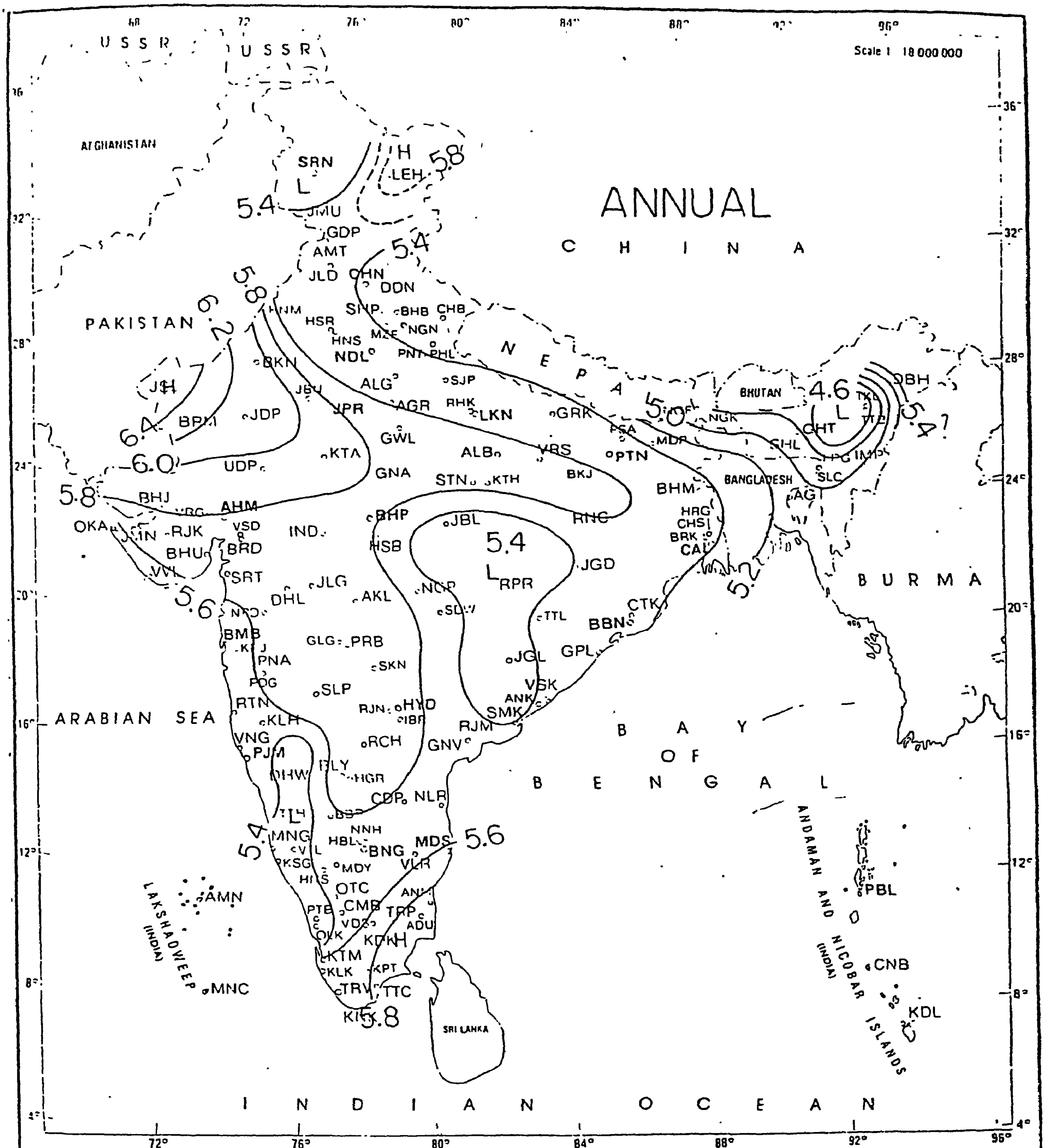
Maximum battery discharge: 20%

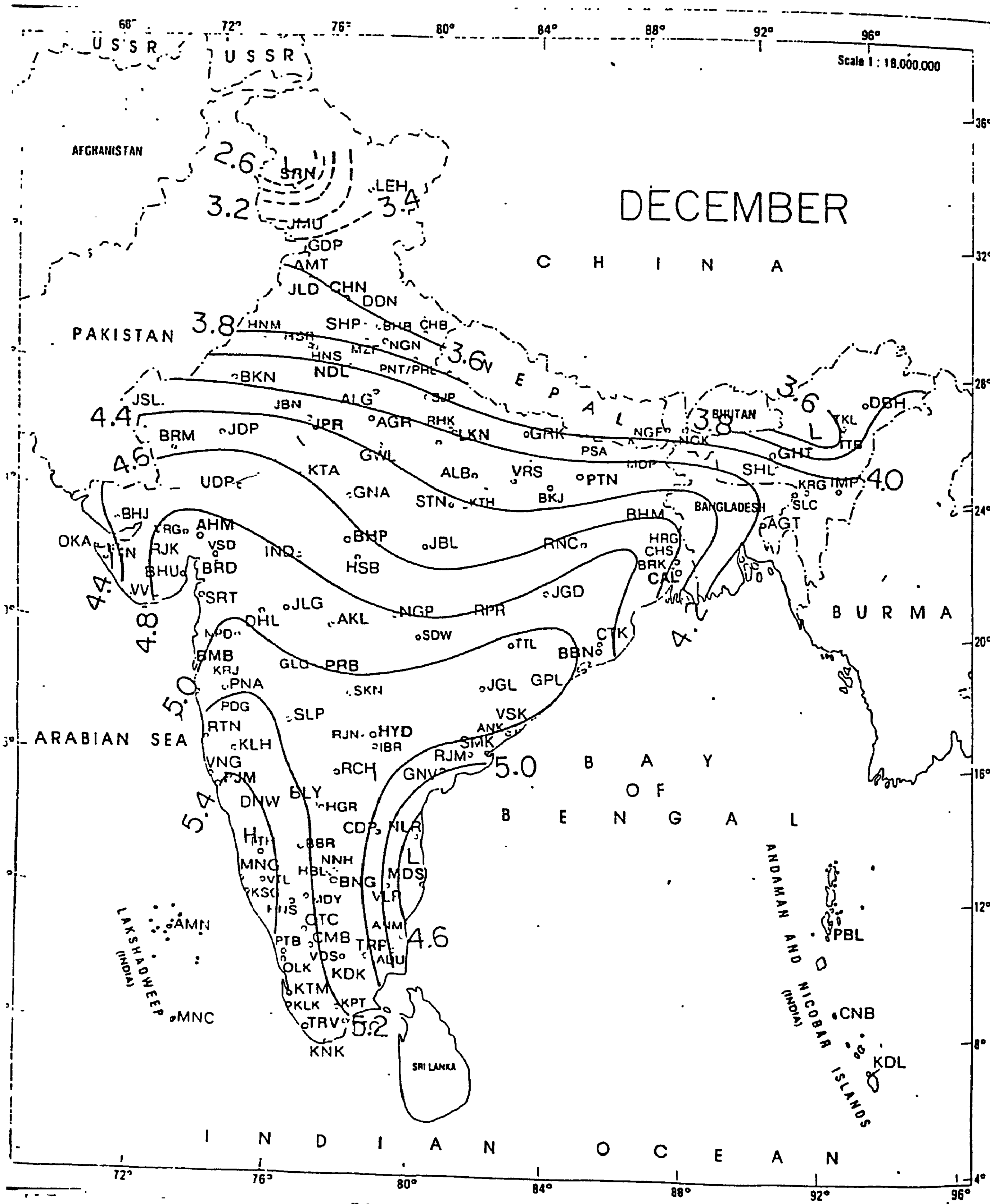
Energy consumption = (8 x 4) + (20W x 4h)
= 112 Wh/day

Array load = 112/ (battery and regulator efficiency)
= 112/ (0.8 x 0.9)
= 115 Wh/day

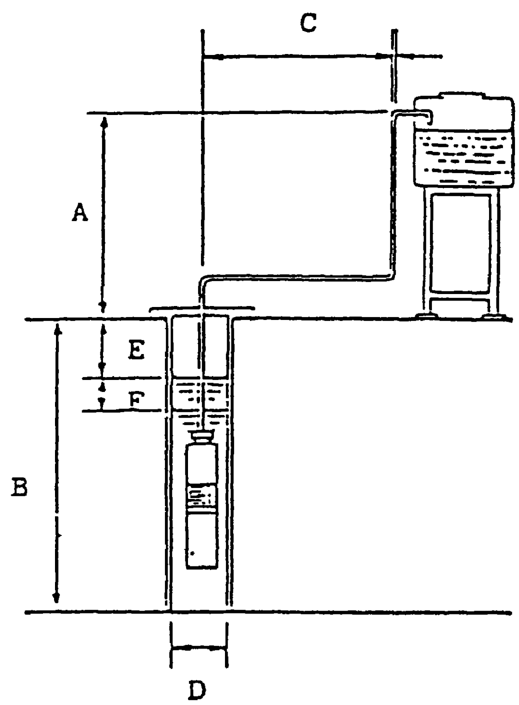
Battery size = $\frac{\text{Daily lamp consumption}}{\text{Max. Discharge x nominal voltage}}$

= 112/ (0.20 x 12)
= 47 Ah


ANNUAL
Scale 1 : 18 000 000
C H I N A
PAKISTAN
AFGHANISTAN
U S S R
N E P A L
BHUTAN
BANGLADESH
B U R M A
ARABIAN SEA
B A Y O F B E N G A L
I N D I A N O C E A N
SRI LANKA
LAKSHADWEEP (INDIA)
ANDAMAN AND NICOBAR ISLANDS (INDIA)
5.4
5.8
6.2
6.4
6.0
5.6
5.0
4.6
5.2
72°
76°
80°
84°
88°
92°
96°
36°
32°
28°
24°
20°
16°
12°
8°
4°


DECEMBER
Scale 1 : 18,000,000
AFGHANISTAN
PAKISTAN
C H I N A
NEPAL
BHUTAN
BANGLADESH
BURMA
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
SRI LANKA
LAKSHADWEEP (INDIA)
ANDAMAN AND NICOBAR ISLANDS (INDIA)
USSR
2.6
3.2
3.4
3.8
3.6
4.4
4.6
4.8
5.0
5.4
5.2
4.6
4.0

Ground Water Supply



Height of storage tank .... A: ....

Depth of well .... B: ....

Distance of tank from pump .... C: ....

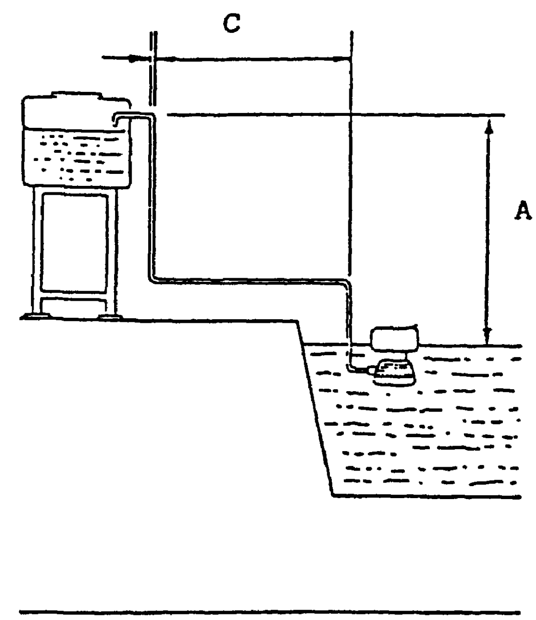
Diameter of well or borehole .... D: ....

Depth of water level E: ....

Drawdown .... F: ....

Pipe diameter ....

Surface Water Supply



Height of storage tank .... A: ....

Suction elevation ...... B: ....
(surface mounted pump only)

Distance of tank from pump .... C: ....

Pipe diameter ....

Seasonal variation of A or B (+ or –) : ....

Proforma for Solar PV pump

Mini-micro hydro power technology

Mini-micro hydro power (MMHP) systems

MMHP is one of the oldest exploited renewable energy sources which has been in existence since the beginning of the 20th century. Even much before that, the technology had been used in the villages in the form of water wheels to provide motive power to run grinders, etc. MMHP enjoys several advantages as an energy source:

i) It is a reliable, mature and proven technology.

ii) It can be operated in decentralised mode as a stand alone system which can meet the lighting and power needs of a remote, inaccessible village. Or else, the system can be synchronized with the conventional grid to strengthen the supply system.

iii) Low capacity systems can be installed on even small water bodies of with sufficient flows provided the head of the fall is at least 2 m and above. Thus, they can be effective even for small applications with low peak demand.

iv) It requires short gestation periods.

v) It does not entail construction of large dams or reservoirs. Environmental impacts such as loss of flora and fauna due to submergence, deforestation and displacement of people usually associated with large hydro power stations are less severe.

vi) The need to lay extensive transmission and distribution lines and hence, transmission losses is completely avoided.

vii) The operation is environmentally benign i.e., no pollution or waste generation.

It is not unusual, therefore, that there are a lot of expectations from this technology and it is being considered as one of the thrust areas for future applications.

Types of MMHP systems

MMHP systems are generally of two basic types viz. *run of the river* and *canal drop* schemes. The former is usually located on a river or its tributary whereas the latter can be found on irrigation canals and water courses. Canal drop installations are generally of low head type, the head varying from 3 metres to about 10 or 15 metres. Run of the river installations have higher heads than canal drop schemes, usually in excess of 30 m because the sites are in the mountainous regions. There is also another category of MMHP installations classified as *dam toe* installations. These are located at the sites where irrigation canals branch off from dam reservoirs. They are, again, of low head type.

Components of MMHP system

An MMHP project broadly has two components: civil works and electro-mechanical works. The primary components constituting the civil works are the diversion structure, water conductor system (power channel), desalting tank, forebay, penstock and powerhouse. The electro-mechanical equipment consists of the generation machinery (turbines, generators and governors), power conditioning and synchronization circuits and transmission equipment.

The diversion structure

It is generally a trench weir[1], dam (permanent or temporary) or any other obstruction, generally constructed at the headworks of the stream from where the required quantity of water is to be diverted for power generation. The trench type weir consists of trapezoidal trough located below the bed of the river. Trash racks are put at the bed of river to stop the boulders falling into the trench. In comparatively small streams however, the water can be diverted during lean season by constructing a low cost barrier. This could be made of boulders, wooden planks, or mud clad tree branches.

On one side of the weir, intake structure and gated desalting tank is constructed. The gate provided at the intake structure is used to control the flow of water in the channel and gate provided in the desiliting tank is used to remove the silt from the bottom of the tank.

Intake structure

This structure is designed to admit the diverted water into the power channel and is located beside the diversion structure at the entrance to the power channel. A suitable regulatory mechanism is usually provided at the intake by means of which flow of water into the power channel can be controlled or completely shut off.

Water conductor system

The water conductor system essentially conveys the water from the headworks to the powerhouse. It consists of the following components.

Power channel. The power channel starts from the headworks (beside the diversion structure) and is designed to carry the diverted water to the forebay or reservoir which is usually directly above the power house.

A trench type weir consists of trapezoidal trough located below the bed of the river. Trash racks are put at the bed of river to stop the boulders falling into the trench.

Desalting tank. This is an essential component of any MMHP installation primarily consisting of a wide tank which enables the water to remain relatively still thus allowing the silt to settle down. A well designed desalting tank can be very effective in protecting the turbines and enhancing their life and performance.

Forebay/reservoir. A forebay or reservoir acts as a final settling area before the water enters the penstock. The primary aim of a forebay or reservoir is to provide for a minimum amount of water to run the machinery for a fixed time even when the water supply in the power channel is cut off due to whatever reason. This time is known as the balancing capacity. Usually there is a valve to control the flow of water at the entrance to the penstock.

Penstock. It is a conduit through which water drops down from the reservoir to the turbine. It is generally made of welded steel pipes of appropriate diameter and wall thickness. The inclination is as close to vertical as possible subject to the local topographical conditions.

Power house. It is a building which houses the machinery viz. the turbines, alternators, governors, synchronization circuits, safety mechanisms, distribution components, etc. Sometimes, there is also a workshop for attending to routine maintenance jobs (see Annexure).

Hydro turbines

Hydro turbines constitute the key elements in an MMHP station whose performance determines the techno-economic success of the station. They convert the energy of flowing water into mechanical energy and rotates the alternator. The primary element in a turbine is the runner which is present on a rotating shaft and has a number of vanes. There are several kinds of turbines depending upon the shape of the runner and casing. Based on the principle of energy extraction, they can be classified into two broad generic types, namely, impulse turbines and reaction turbines. Impulse turbines use the velocity of water to drive the runner while reaction turbines use the pressure of water. Depending upon their design and constructional features, they are further subdivided into a number of sub categories as illustrated in Figure 1.

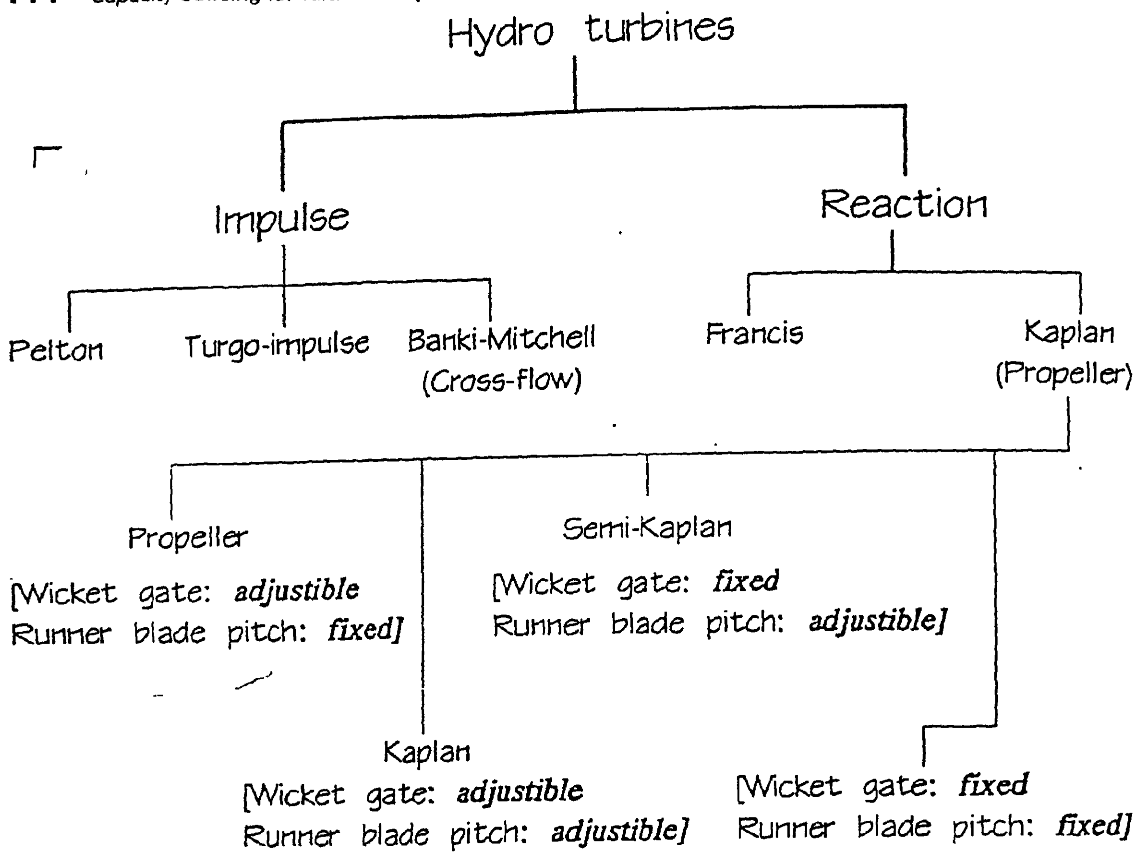


Figure 1. Classification of Hydro-turbines used in MMHP projects

Generator

The turbine is usually directly coupled to the generator through a flywheel of suitable size. The coupling could also be through speed increasing gears or through belt-pulley drive for smaller units usually less than 100 Kw. Speed-increase enhances the rotational speed of the generator, thereby reducing its size and consequently the cost.

The generators could be synchronous or asynchronous types. Synchronous generators have their own excitation system whereas the asynchronous ones (induction generators) have to depend on external sources like utility power supply system for providing power to the field coils. Thus, synchronous generators are more sophisticated and versatile in application though more expensive.

The hydro-turbine driving induction generators requires simple controls for starting, loading and stopping, whereas an elaborate system including synchronization facility is required when driving synchronous generators. For isolated operation, synchronous generators are preferable, because they outweigh the induction in cost terms.

Governor

The function of a governor is to cut off the water supply to the turbine in case of a sudden tripping of load or to suitably alter it in case of variations in the load. The governors

employed in most installations in India are of mechanical (oil pressure) type which operate by maintaining constant RPM of the system. Recently, electronic governors have also been introduced.

Tail race

The tail race is a channel which directs the outcoming water from the turbine back to the stream. In case of multiple turbine units, the outlet channels of all the constituent turbines of the powerhouse either join together or empty into a single channel to form a common tail race.

Classification of MMHP systems

MMHP systems cover a wide range of sizes and capacities. On different occasions they have been classified or grouped into different sub classes. In India, however, the classification adopted is as follows:

Depending on the capacity :

Size	*Unit size*	*Installation*
Micro	up to 100 Kw	100 Kw
Mini	101 to 1000 Kw	2000 Kw
Small	1001 to 6000 Kw	15,000 Kw

Depending on the Head:

Ultra low Head	Below 3 metres
Medium Head	Between 30 to 75 metres
High Head	Above 75 metres

Sizing of the MMHP project

When an MMHP installation is planned for isolated mode of operation with no pondage, the installed capacity is decided on the basis of minimum flow. This results in minimum cost of generation. When it is planned to operate the MMHP installation in parallel with the grid, the installed capacity is decided on the basis of marginal cost.

Selection of hydro-turbine

Selection of an appropriate type of turbine is based on the considerations of site conditions, namely, head and head variation, discharge and discharge-variation and load variation. Each type of turbine has an operating range over which its performance is technically acceptable. Charts for turbine application have been developed by many of the

manufacturers indicating the head and discharge ranges over which a particular type of turbine is more appropriate than others. In India, mostly Turgo-impulse and Francis turbines have been installed.

Axial setting of a turbine

The turbine-generator axis arrangement in a hydropower station can be either vertical, horizontal or inclined. The vertical axis arrangement is adopted universally for the medium and large hydropower stations and the horizontal axis arrangement for MMHP stations.

Economics of MMHP in India

The general rule "smaller the size, higher the cost" also applies to mini-micro hydro technology. However, there are a number of measures which can be adopted to reduce the costs of installation and operation of MMHP plants. Unfavourable conditions with respect to economics, usually associated with MMHP are:

i. High specific cost (i.e. per Kw installed capacity)
ii. Low load factor particularly when used in decentralized/ stand-alone mode of operation.
iii. Little or no peaking capacity
iv. High operation and maintenance cost.

Depending upon a number of factors such as the distance, down time, natural/climatological factors, etc., the installation costs of MMHP can vary widely from about Rs 50000 per installed kilowatt to more than Rs 90,000 per installed Kw. Generation cost for MMHP installations similarly varies substantially, being more than Rs 2 per Kwh for installations below 3 MW, and from Rs 1.45 to Rs 0.72 per Kwh for installations above 3 MW an large hydro. Thus, MMHP generation cost for units having an installed capacity below 3 MW is over 10% higher than large thermal power plants which cost from about Rs 1.38 to Rs 1.85 per Kwh.

The latest MNES benchmarks for capital costs of MMHP schemes and the generation costs are as follows:

Capital costs

Canal based schemes	-	Rs 35 to 50 million /MW
Schemes in hilly areas/NE region	-	Rs 50 to 90 million /MW

Cost of generation

All schemes	-	Rs 1.50 to 3.50 /kWh (depending upon the terrain and available head)

Application/ relevance of SHP in the rural areas

Small hydro plants in rural areas can play a significant and viable role in rural development and rural electrification. The small hydro plants are significantly useful in that areas where the extension of grid electricity is difficult.

It can be used for the battery charging in the areas where the extension of the grid impossible Micro hydro power can be used for food processing industries in rural areas

- Agro processing: rice milling, grinding, oil extraction, etc.
- Rural industries can be benefited from hydro power
- This can be used for low wattage electrical cooking
- Overall generation of employment for the rural youth.

Calculation of power from MMHP

The power from an MMHP site is directly proportional to the quantity of water flow and the height (head) which is available. This can be represented as follows:

Power = Quantity (Flow) × Head (height of fall) × Constant × System efficiency

$$P = Q \times H \times 9.81 \times 0.80$$

Where, P is in kilowatts

Q is in Cubic meters per second (cu.m.)

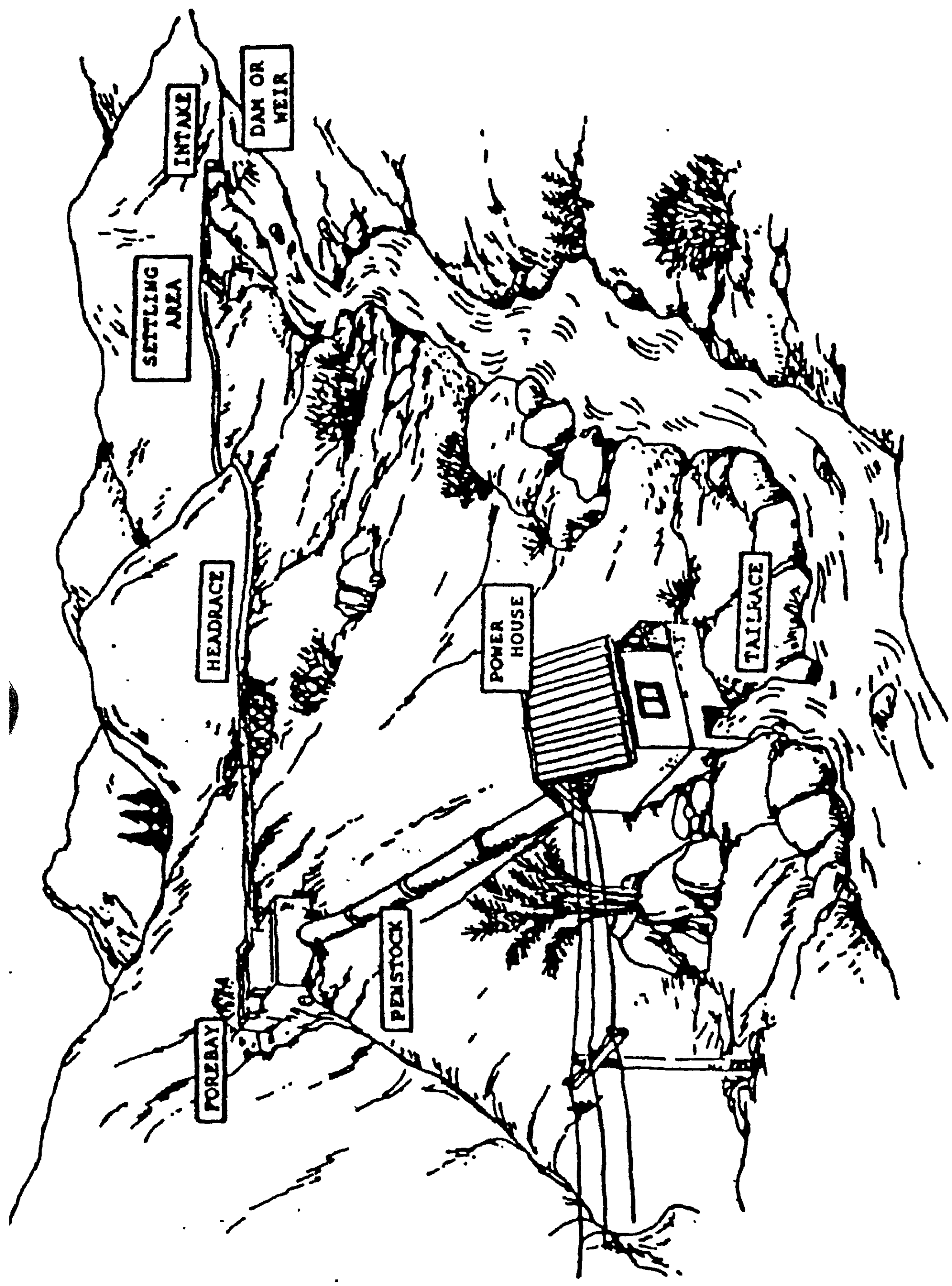
H is in metres (mts)

9.81 is the gravitational constant (mts/sec^2)

The system efficiency is generally taken to be about 85%.

ANNEXURE

Components of a hydroelectric scheme



Wind Power Technology

Background

As a result of the increasing attention directed towards alternative forms of energy and methods of conversion, the significance of renewable energy devices operating in the dispersed and decentralized mode as serious components of modern energy supply has been growing. Wind energy is one of the clean and renewable energy sources which hold out the promise of meeting a significant portion of energy demand in the direct grid-connected modes, stand-alone and remote 'niche' applications (e.g., water pumping, desalination, and telecommunications), in developing countries like India.

Large scale utilization of wind energy for power generation in the USA (California), Europe and India and demonstration projects in several other developing countries have established beyond doubt its viability in windy regions (Table 1).

Table 1. Wind power generation

Country	Capacity MW	
	1992	December 1995
United States	1720	1654
Denmark	470	637
Germany	170	1132
United Kingdom	100	201
The Netherlands	116	249
India	42	576
Spain	45	133
China	15	44
Sweden	7	69
Italy	6	33
Others	15	169
Total	2706	4897

In developing countries, wind technology plays a very important role in meeting the increasing energy needs while ensuring sustainable development. There has been a general increase in concerning towards wind energy technologies all over the world. A great deal of interest is being shown by media, academicians, students, international funding and aid organizations, environmentalists, industries, and policy makers. Of late, an increasing number of people are seeking information on wind powered systems than ever before. The wind power status in India is given in table 2.

Table 2. Wind Power: Installed Capacity (in MW) at a glance (As on 31.03.1996)

State	Demonstration Projects	Private Sector Projects	Total
Tamil Nadu	19.355	537.035	556.390
Gujarat	16.345	99.328	115.673
Andhra Pradesh	3.050	41.850	44.900
Karnataka	2.575		2.575
Kerala	2.025		2.025
Maharashtra	2.600		2.600
Madhya Pradesh	0.590	6.300	6.890
Orissa	1.100		1.100
Others	0.465		0.465
Total	48.105	684.513	732.618

Wind electric system

Grid Connected WEG

The Grid-connected Wind Electric Generators (GCWEG) have been installed on the largest scale and most of these systems are Horizontal Axis Wind Turbines (HAWTs). The systems described in this section are also HAWTs. The GCWEGs are produced in a wide range of ratings and sizes varying from 50 to 6000 Kw. However, the largest number of machines installed so far lies in the 100 to 300 Kw range. It is felt that in the very near future most of the commercially available GCWEGs will be in the range of 0.5-1 MW.

Subsystems of GCWEG

The major subsystems and components of GCWEG are briefly described below:

Structure. The main components of the structure are the tower, the nacelle, and the foundations. The tower height is normally recommended by the suppliers who allow a certain minimum clearance between the lowest tip of the blade and the ground level. Towers are either tubular or of the lattice type. Both, tubular and lattice towers are usually made of galvanized steel. However, concrete towers of the tubular type are also in use. The nacelle is basically the engine bed of the turbine supporting and containing all the machinery, i.e. rotor shaft, gear-box, hydraulic brake mechanism, generators, yaw mechanism, some controls and other accessories. The nacelle is mounted on the top of the tower such that it can be rotated about the tower axis by the yawing mechanism. The nacelle rests on the tower top on pads

which are free to move and hence allow for the yawing movement of the nacelle. The nacelle and its contents are covered by a Fibre Reinforced Plastic (FRP) or metal cover.

Prime mover The prime mover of a wind turbine is usually known as a rotor. The rotor in the case of GCWEG has a horizontal axis and consists of 2 or 3 blades. These blades, which have an aerofoil section, are fixed to the hub[1]. While aluminum blades were used earlier, most of the blades manufactured today are of FRP. Wood-epoxy has also been tried in some cases with reasonable success.

Transmission. The transmission system of a GCWEG is housed in the nacelle. The gearbox normally consists of a two stage gear train for stepping up the r.p.m. from 30-40 to 1100-1200. In the case of small wind generators, the transmission system consists of the rotor shaft directly coupled to the generator, which is housed in the nacelle usually made of FRP. The turbine is protected from high wind speeds by auto-furling of the tail.

Generating unit. As mentioned above, the generating unit is also mounted in the nacelle. Most of the GCWEG have an induction generator as the power generating unit. The use of synchronous generators is limited. This is due to various advantages associated with cost, construction, and operation of induction generators.

Control unit. The main functions of the control unit are protection and regulation of the system. A control unit can be a relay-based system or a microprocessor-based system. The typical functions of the control unit are listed below:

Protection against overspeed of the propeller.
Protection against high wind speed.
Protection against high vibrations.
System protection against grid supply fluctuations.
Overload protection.
Temperature faults.
Yawing.
Indicators.
Counters/meters.

[1] The blades are attached to a casting (or fabricated part) called as *Hub* which in turn is connected to the rotor shaft.

Hybrid WEG

For supplying electricity to villages not connected with grid, hybrid wind electric system can be used. Hybrid wind electric systems are operated with a diesel engine backup or can be a combination of wind, solar and diesel engine. The components/sub-systems of the turbine in hybrid systems are similar to those of grid- connected wind turbines described earlier. However, there are major differences in controls, wind-fuel interphase, storage, and power regulation. Storage is needed to limit the start and stop cycles of the fuel engine and to ensure the reliability of supply. Autonomous systems in the strict sense are seldom used as some storage backup is always there. Hybrid systems are being used for rural electrification in countries like Australia, the technology has good potential for rural electrification in coastal India.

Mechanical output wind machines

The mechanical output wind machines are mostly used for pumping water. Direct shaft power has also been tried in other applications like grinding. The use of windmills for grinding grains, which has been one of the applications of traditional windmills, has declined now.

Windpump Technology

At present, nearly all mechanical output windmills are used for pumping water and the system is known as a windpump. The most widely used windmills are those that have horizontal axis rotors with multiple blades. The rotary motion of the rotor shaft is converted to either vertical reciprocating motion by various mechanisms with or without speed reduction (by gears). Some machines also use bevel gears. The vertically reciprocating pump is connected to a reciprocating pump which demands high initial torque whereas the vertically rotating pump rod is connected to either a centrifugal pump or a rotary vane pump. The rotary movement by means of a crank-connecting rod.

The major sub-systems of a windpump are:

Rotor. . The rotor of a windmill consists of a varied number of blades (4-24) mounted on one or two rings (depending upon the diameter) and spokes which are bolted to the rotor hub. The blades are made of either aluminum, M.S. sheet, G.I. sheet or FRP and are fixed aerodynamically to the rotor. The rings, spokes and blade supports are fabricated of steel angle irons or flats. The rotor, however, can also be of other types like vertical axis Savonius, with sailcloth blades, etc.

Head structure. The head structure of a windmill is usually fabricated of angle irons/pipes or is cast in a foundry. The rotor, tail wing, and the power transmission components are mounted on the head structure.

Turn-table: The turn-table made of steel is fixed to the tower and the windmill head structure is mounted on it. The turn-table transmits the load of the rotor, head structure, tail wing, etc. to the tower and at the same time enables the head structure to rotate about the tower axis.

Tower. The tower is made of M.S. angles and flats or G.I. pipes and is usually in two or three sections. It holds the head mechanism at a height that varies from 6 to 15 m. Towers are usually three-or four legged lattice structures.

Pump. The most widely used windpumps operate a single acting reciprocating pump. The reciprocating piston pump consists basically of a cylinder made of brass/bronze with or without cast iron covering, a piston and two non-return valves. The upper valve is mainly situated in the piston; the lower valve is called the foot valve. The operation is that the upper valve closes with the upward movement of the piston when the foot valve opens so that the water above the piston is lifted while suction takes place below it.

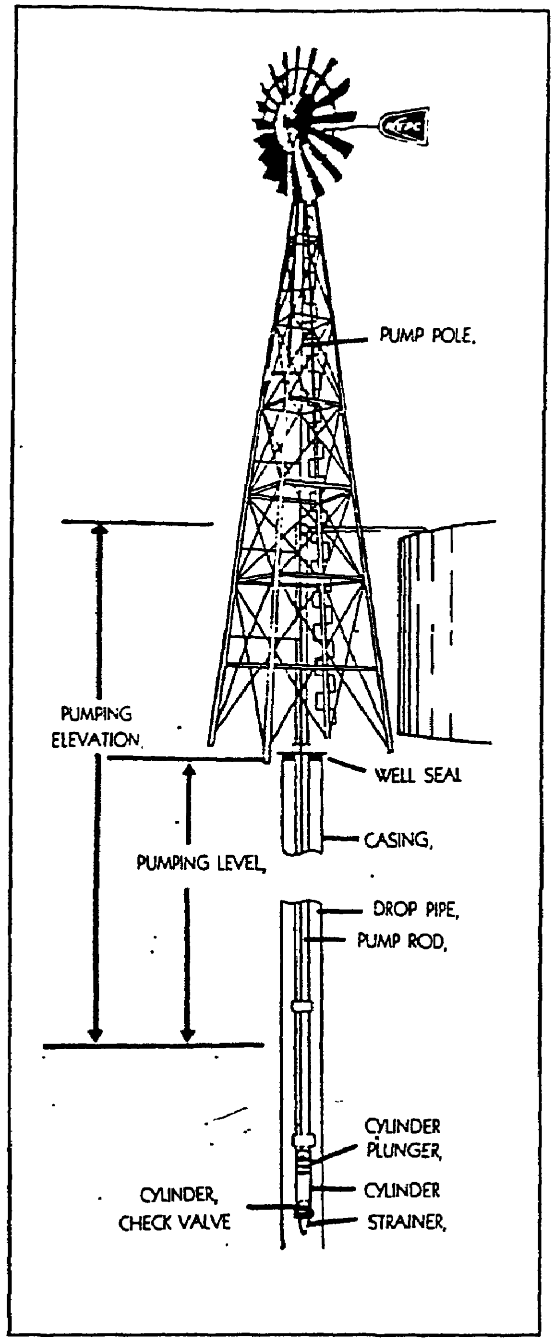


Figure. The components of a geared type deepwell wind pumping system

Control and safety mechanism. Windmills are designed/fabricated to operate within a particular range of wind speeds. The control mechanism operates within this range. It controls the rotor speeds and the safety mechanism operates after the operating range when it stops the operation of the system. Autofurling, side vane and ratchet mechanism, brake drums, etc. are examples of control and safety mechanisms.

Developments and Status

Windpumps first arrived in India in the 1950s. About 100 Australian windpumps were imported, to be used for providing drinking water. After the setback during the industrial revolution, wind energy received a major thrust in the early 70s following the oil crisis. Multidirectional CEZARI was developed in 1975, the bi-directional ANILA - I in 1978 and the NAL-MP series was developed in early 1980. IERT, Allahabad with technical backup from the Tool foundation, The Netherlands, fabricated the APOLY 12 PU 500 windpump based on a Dutch design. This project was aimed at harnessing wind power for irrigation.

The absence of a national programme to take this technology to all parts of the country was felt by this time. Hence, in the beginning of 1980, MNES started nationwide demonstration programmes. The 12 PU 500 windpump was selected for this programme mainly due to its low outlay, promising technology and zero fuel cost.

However, the field performance of the system was not as satisfactory as expected due to reasons, both technical, and of implementation strategy. Currently, MNES has shifted to geared type deepwell wind pumping systems. The main reason for this change was the poor performance of 12 PU 500 in the field even after several design modifications and varying implementation strategies. Other possible reasons are water table dropping deeper and the fact that the geared type deepwell technology has been proven in foreign countries. The specifications of typical 3m gear - driven windpump are given in the table 3.

Table 3. Specifications of a typical 3m gear-driven windpump

Rotor Diameter	3m
Tower height	10m
Number of blades	18
Cut in windspeed	6 km/hr
Rated windspeed	13 km/hr
Cut out windspeed	35
Designed maximum windspeed	80
Gear ratio	3.29
No of gears	2
Stroke per minute	26
Stroke length	7.25/9.25 inch.
Space required	3m × 3m

The pump capacities have been given in the table below:

Table 4. Pumping Capacities

Diameter of cylinder (inches)	Pumping capacity of 3m rotro (l/hr)	Pumping elevation for 3m rotor (feet)
1.75	750	280
2.0	950	260
2.5	1625	140
3.0	2350	100

The cost of a typical wind pumping machine is around Rs. 65,000 only.

Assessment of wind potential

Power that can be harnessed from wind energy generators is proportional to the cube of the wind speed and is given by the formula.

$$P = C_p \times \tfrac{1}{2} \rho AV^3$$

Where. P = power in Watts

ρ = density of air in kg/m^3

C_p = Coefficient of performance of turbine

V = Wind speed in m/s

A = Area through which the wind blows. in m^2

Thus if the wind speed doubles, the power available (water pumping capacity) increases eight folds. However. for a preliminary assessment during the selection of a site should be made on the following benchmark in wind speeds:

a) For **Wind pumps** it is sufficient that the place receives gentle breeze throughout the day. i.e.. about 3-4 metres per second wind speeds should suffice.

b) For **Wind electricity generators**. much higher wind speeds are required. A site is considered suitable if the annual wind speed is in the range of about 6 m/s. This means that in the windy months - from June to September. the wind speeds should be in the order of about 11-12 m/s and this could be even higher. say up to 25 m/s.

Economics of wind energy

The cost of a typical wind farm would be about Rs. 3.5 - 4.0 crores per MW (installed). depending on the site. The cost of machines contributes to about 855 of the project cost of

windfarms (up to 5 MW). The following table shows the typical cost of turbines of different capacities:

Table 5. Cost of turbines

Turbine capacity	Cost (in lakhs)
225	60
250	75-85
400	80
600	215

The cost of generation from a small wind farm at a good site, varies in the range of Rs 2.25 to Rs 3.00/ kWh.

The details of the organisations involved in the promotion of wind energy technology is given in the Annexure.

ANNEXURE

The following organizations/institutes are active in the field of wind energy.

The Ministry of Non-conventional Energy Sources (MNES), New Delhi

In order to provide a major thrust to and better focus on non-conventional and renewable sources of energy (NRSE), the Government of India has expanded the earlier Department of Non-conventional Energy Sources to a full-fledged ministry. The general objectives of MNES are given below:

(a) Promoting research, development, demonstration, dissemination, and popularization of NRSE technologies for harnessing the available solar, wind, hydro, biomass, ocean, geothermal, hydrogen, and chemical energy sources.

(b) Providing financial incentives to users and manufacturers in the form of subsidy, soft term loans, and fiscal incentives.

(c) Promoting the creation of institutional, implementation, and monitoring infrastructure in different states of the country for research and development: training and dissemination of various renewable energy technologies.

(d) Assessment of renewable energy resources potential for different regions of the country.

(e) Framing of appropriate policies for achieving the various objectives of development, dissemination and commercialization of renewable energy technologies.

All activities concerning wind power in the country are undertaken by the Wind Power Division of MNES.

Indian Renewable Energy Development Agency (IREDA), New Delhi

The Indian Renewable Energy Development Agency Limited (IREDA), a public limited government company under the Companies Act, 1956, was established in March 1987. Its objective is to operate a revolving fund for development, promotion and commercialization of new and renewable sources of energy through provision of short term financial assistance in the form of soft loans. Its operations have been increasing from year to year.

The major objectives of IREDA are,

(a) promotion of commercialization of renewable resource technologies;

(b) creation, marketing and financing of mechanisms for the sale and delivery of alternative energy systems;

(c) institution of a framework for encouraging private sector investments in small scale power generations; and promotion of environmentally sound investment to preserve forest resources.

The State Nodal Agencies

The policies, incentives and funding of MNES for development and propagation of the NRSE technologies are implemented at state level through the state nodal agencies. These agencies, though run by the state governments implementing their policies and initiatives for these technologies, mainly act as the implementing organizations of MNES.

The State Electricity Boards

The state electricity boards play a major role in the installation of NRSE power plants. In the case of windfarms, each of these has to be connected to a nearby sub-station or a new sub-station has to be made in order to interface the windfarm to the power grid. The grid is then used to convey the power to the beneficiary. It is here that the state electricity boards provide their services and expertise.

Other Research Organisations/Institution

1. Indian Institute of Science, Bangalore
2. Indian Institute of Technology, Madras
3. Tata Energy Research Institute, New Delhi
4. Indian Institute of Technology, Kanpur
5. National Aeronautics Laboratory, Bangalore
6. Indian Institute of Technology, Delhi

Energy plantations

Introduction

Biomass continues to be the main source of energy in the country and accounts for about 40 percent of the total energy consumption. Out of various biomass fuels, the share of fuelwood is more than 68 percent. However, there exists a wide gap between the demand and the supply of fuelwood, leading to deforestation and soil erosion, with consequent environmental degradation. Since the importance of wood and biomass energy is unlikely to decrease in the coming years, it becomes imperative to develop efficient options for biomass production and utilization. A vast potential for biomass lies in the plantation of fast growing tree and shrub species with high biomass yields, that can be planted on the marginal lands and wastelands.

Energy plantations

Energy plantations are short rotation, high density, intensively managed plantations of fast growing tree and shrub species, specifically for the purpose of meeting the fuelwood requirements of the local people. They provide an effective way of satisfying the local energy requirements in a decentralized manner. The biomass obtained from the energy plantations may be directly converted into useful energy through direct combustion in cookstoves or for decentralized use through refined technologies such as pyrolysis, gasification, conversion into liquid fuel, etc.

There are several advantages of energy plantations apart from providing a inexhaustible, renewal source of energy. Establishment of these plantations can help in reducing the dependence and demand for other fuels. Unlike fossil fuels, pollution from wood is less and the ash obtained after burning is a valuable fertilizer, thus preventing problems of waste disposal. These plantations can also be a useful tool for reclamation of wastelands and stabilizing soil conditions.

Raising bioenergy plantations

Successful tree husbandry depends on several factors among which are -

(a) Selecting the most appropriate species
(b) Using good quality seeds
(c) Raising healthy seedlings for transplanting
(d) Correct species and site selection
(e) Using appropriate planting practices
(f) Adequate aftercare (weeding, protection, etc.)

It is important to keep in mind the soil moisture requirements of the selected species, soil pH, resistance to pest and diseases, susceptibility to fire and browsing etc. One of the serious risks to energy plantations may be from destruction due to pests and diseases. However, it is generally felt that exotic species should be avoided unless they are far superior to the indigenous species. Short rotations of the energy plantations also reduces the risks of disease and pests. The regular shape and compactness of energy plantations facilitates intensive management and protection.

Species suitable for energy plantations should have the following desirable attributes -

a) **Ability to produce wood of high specific gravity** even when grown rapidly in short rotations. Higher specific gravity of wood means more weight of wood produced per hectare, for example-*Acacia catechu*, *Casuarina equisetifolia* etc.

b) **High wood calorific value** - The range of calorific values of wood is fairly narrow. However, among the species on the higher side are *Samanea saman*, *Albizia lebbeck*, etc.

c) **Capacity for rapid growth on a wide range of sites**- Table 1 gives data on some fast growing species and the expected yields.

d) **Stem and crown architecture enabling very close tree spacings** to be maintained over short rotations of about 4-8 years - Only some species, with straight, upright stems and narrow columnar crowns can tolerate close spacing like, *Eucalyptus spp.* , *Casuarina spp.*,etc. Some species like *Leuceana leucocephala* which produce multiple straight stems from a single stump can also produce high yields.

e) **High above-ground biomass production on a range of sites** - Bioenergy plantations should be raised with those species on appropriate sites such that yield is not less than 10-20 t/ha/yr over 5 year rotation periods.

f) **High solar energy conversion efficiency** - Of the total amount of the photosynthetically active radiation that falls on the plants, only a small amount is absorbed and fixed in plant woody tissues to be released later on burning biomass. The best species include *Sesbania grandiflora* and *S.sesban*, *Eucalyptus camaldulensis* while the poor species include *Albizia falcataria*, *Eucalyptus grandis*, *Casia siamea*, etc.

g) Preferably multipurpose, including the **ability to fix atmospheric nitrogen**. Nitrogen fixing tree species are especially important for degraded soils. Examples of some nitrogen fixing trees are given in Table 2. For species that do not fix nitrogen, underplanting of leguminous shrub and ground covers can compensate the loss of nitrogen from the soil to a certain extent.

Biomass programme of the ministry of non-conventional energy sources (MNES)

The research and development programme on biomass energy of the MNES aims at screening and selecting high-yielding and short-rotation fuelwood tree species, besides developing and promoting suitable packages of practices for better survival and improved productivity of the selected tree species for different agro-climatic zones of the country. A demonstration programme for promoting indigenously developed gasifier technology is also being implemented to ensure efficient utilisation of fuelwood and agro-industrial wastes for various energy applications.

Biomass Research Centres (BRCs) are functioning in nine different agro-climatic regions of the country (Table 3). Work is in progress on 70 fast growing fuelwood tree species. The productivity of selected fuelwood tree species is assessed under field conditions and efforts are being made to develop detailed packages of practices, including standardisation of nursery requirements, application of biofertilisers and insect, pest and disease control measures The BRCs have already finalised the packages of practices for about 25 fuelwood species, which are highly suitable in a given agro-climatic region as indicated in Table 4 and have been published in Hindi and Regional languages for wider dissemination.

All the BRCs have been organising training programmes for different targeted groups, such as farmers, resource persons of implementing agencies, non-governmental organisations (NGOs), district and block level officers of various State Governments and representatives of industries and panchayats.

Table 1. Biomass yield of some fast growing species

Name of Species	Age	Yield (t/ha)	Yield (t/ha/yr)	Source
Cassia siamea	5	82.5	16.5	RPRC, Bhubaneswar
Leuceana leucocephala	5	62.5	12.5	- do-
Casuarina equisitifolia	5	31	6.2	- do-
Acacia auriculoformis	5	60.6	12.12	- do-
Gliricidia sepium	3.5	25.13	7.18	- do-
Trema orientalis	3	54	18	- do-
Albizia stipulata	5	101.4	20.28	Srinagar
Prunus cerasoides	7	122.5	17.5	- do-
Acacia catechu	6	116.64	19.44	- do-
Alnus nepalensis	5	82.4	16.48	- do-
Albizia lebbek	6	120	20	- do-
Ougenia dalbergoides	6	97.68	16.28	- do-
Leuceana leucocephala	3	110.4	36.8	MKU, Madurai
Albizia lebbek	3	60	20	- do-
Hardwickia binata	3	100.5	33.5	- do-
Samaniâ saman	5	80.1	26.7	- do-
Cassia siamea	3	62.1	20.7	- do-
Erythrina indica	3	79.8	26.6	- do-
Prosopis juliflora	8	96.49	12.06	NBRI, Lucknow
Terminalia arjuna	6	42	7	- do-
Acacia nilotica	8	59.5	7.43	- do-
Acacia auriculoformis	8	54.54	6.82	- do-
Prosopis juliflora	8.5	187	22	NARI,Phaltan

RPRC - Regional Plant Resource Centre
MKU - Madurai Kamraj University
NBRI - National Botanical Research Institute
NARI - Nimbkar Agricultural Research Institute

Table 2. List of nitrogen fixing tree species

Species with Nitrogen-fixing ability	*Species without nitrogen fixing ability*
Acacia auriculiformis	Artocarpus heterophyllus Azadirachta indica
Acacia cataechu	Cassia siamea
Acacia nilotica	Eucalyptus camaldulensis
Acacia mangium	E.grandis
Albizia procera	E.globulus
Albizia lebbeck	E.Tereticomis
Cajanus cajan	Melia azaderach
Casuarina equisetifolia	Moringa oleifera
Dalbergia sissoo	Syzygium cumini
Emblica officinalis	
Leuceana leucocephala	
Samanea saman	
Sesbania grandiflora	
Sesbania sesban	

Table 3. List of fuelwood species on which package of practices have been developed by different BRCs

Biomass Research Centres	Agro Climatic Region	Fuelwood Species
National Botanical Research Institute, Lucknow, U.P	Upper Gangetic Plains	Acacia nilotica Prosopis juliflora Dalbergia sissoo
High Altitude Plant Physiology Research Centre, Garhwal University, Srinagar, U.P	Western Himalayan	Alnus nepalensis Bauhinia retusa
Madurai Kamaraj University, Madurai, T.N.	Southern Plateau & Hill	Hardwickia binata Eucalyptus camaldulensis Glircidia sepiun
College of Technology & Agricultural Enggineering, Rajasthan Agricultural University, Udaipur Rajasthan	Central Plateau & Hill	Acacia tortilis Albizzia lebbek Prosopis cineraria
Regional Plant Resource Centre, Bhubaneshwar, Orissa	East Coast Plains & Hill	Acacia auriculiformis Cassia siamea Casuarina equisetifolia
Tata Energy Research Institute, Gwalpahari, Gurgaon, Haryana	Trans-Gangetic Plains	Haplochraga adenophyllu Terminalia arjuna Melia azaderach
University of Calicut, Calicut, Kerala	Western Plain & Ghat	Eucalyptus grandis Macaranga indica Terminalia catappa
Ravi Shankar University Raipur, M P	Eastern Plateau & Hill	Cleistanthus colinus Lagerstromia parviflora Peltophoru deltoides
Vishwa Bharti, Santhiniketan, W.B	Lower Gangetic Plains	Acacia nonilitorais Artocarpus heterophyllus

Session IV

Policy Issues

The various issues to be considered while formulating rural energy policies have been discussed in this session. The objective is to enable the participants to understand the relevance of these issues and develop a broader perspective.

Contents

- Technology issues
- Financial issues
- Institutional issues
- Gender issues
- Community participation
- Programme integration

Issues in rural energy policy

Introduction

From the present supply-demand scenario, it is clear that biomass would continue to be the mainstay of the rural energy sector in the foreseeable future. The penetration of various commercial fuels will remain quite low, and at the present rate, it would take a long time for renewable energy technologies to make any significant impact on the sector. Therefore. any policy formulated to deal with rural energy will have to look for highly innovative options and make judicious investment choices. There are several issues to be considered while formulating such policies. These are:

Technology choices

The principal thrust of any meaningful rural energy policy should be to effect a shift from the present ***traditional*** biomass technologies to ***efficient*** biomass technologies which provide greater energy service with same resource. Presently, however, the choice of technologies available is quite limited and their impact is too low and slow. One of the reasons for this situation is the low priority attached to research and development. For instance, the investment made in the R & D of renewable energy technologies is just about 4.6% of the total expenditure of the MNES between 1982 and 1994. Therefore, developing a focussed and target-oriented R & D programme should be a top priority in developing and demonstrating the new technologies. The main objective of such a programme should be to come up with technologies which are low-cost as well as highly efficient, and suitable to meet local practices and lifestyles.

Dissemination approach

Most rural energy programmes so far have been run as centralised, target-oriented programmes exclusive of other programmes. However, the experience suggests that while determining the feasibility or adaptability of a particular programme or technology, it would be important to consider the priorities of the local people, and bring about an integration of various development programmes. For instance, improved cookstove programme can be effectively combined with rural housing making it mandatory for all new government-constructed houses to install these devices as part of the design itself. Likewise, biogas dissemination can be done in conjunction with rural sanitation programmes, solar photovoltaics with rural communication, etc. However, such an

integration would be possible only if a decentralised planning method is adopted, and the local participation ensured[1].

Commercialisation

The issue of market orientation has become important in view of the changes taking place in the economy. However, as far as rural energy technologies are concerned, none of them is at the stage where it could be completely commercialised across all parts of the country. Therefore, it is important to identify those technologies and those areas where this would be possible, and take up the task of commercialisation[2]. Also, it is critical to identify the barriers (technical, financial, social, institutional, etc.) for commercialisation, which could be different in different regions, to formulate appropriate strategies[3].

Capacity building

Apart from the various aspects related to the planning and implementation of rural energy programmes, the experience has shown that lack of adequate infrastructure and trained personnel at the operational level has led to several failures. Therefore, it is critical to develop this at the local level which could be done in two ways:

(i) involve the NGOs at the grassroots level actively in planning, implementation and management of the programmes; and

(ii) develop rural entrepreneurship by initiating innovative fiscal and financial packages including access to soft credit[4].

Another opportunity is the involvement of local government bodies like *panchayats.*

Some recent developments

Following the liberalisation process that was put into motion at the beginning of the VIII Plan, there have been major changes in the energy sector in India with more emphasis on

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[1]In the Indian context, the following classification is suggested for decentralised rural energy planning: plan at the district level; programme, denoting a group of projects for a cluster of villages at the block level; and, project at the village level.

[2]For instance, it is reported that in pockets of Maharashtra, Andhra Pradesh, etc. biogas technology has reached a level of acceptance where people are willing to acquire them without the subsidies or soft loans.

[3]It may also be relevant to review the role of MNES in this regard. So far, MNES has been the planner as well as implementing agency with a centralised approach as reflected in the national programmes. It could now consider playing just the role of a facilitator, and re-allocate the budget from direct subsidies towards more of R&D, training, etc.

[4]The turnkey entrepreneur approach used in the biogas programme has been quite successful in several parts of the country and could be a good model to adopt.

entrepreneurship and commercialisation. Some of this has had an impact on the rural energy sector, too. The following are some of the new developments taking place which might have longterm implications for the rural energy sector.

(i) As mentioned earlier, rural electrification has always meant extension of grid. Now there are attempts by the Rural Electrification Corporation (REC) to include small hydro and photovoltaic technologies to produce electricity in a stand-alone mode. This move would greatly help in reaching the electricity to remote and inaccessible areas which may not achieve electrification otherwise.

(ii) There is an emphasis on promoting rural entrepreneurship in promoting energy programmes. For instance, MNES has the aim to achieve 75% of the targets in biogas and improved stove programmes through involvement of turnkey entrepreneurs and NGOs. This approach has already led to positive results.in some parts of the country.

(iii) The Panchayati Raj Bill promulgated through an amendment of the Indian Constitution envisages devolving financial powers directly to the Panchayats (village councils), and provides for 30% representation for women in the councils. Thus, if proper awareness is created about the need for sustainable energy development, this can be used as an effective institutional mechanism.

(iv) The MNES is currently in the process of formulating a legislation to be introduced in the Parliament of India on the renewable energy sector. This is aimed at providing a regulatory framework for promoting renewable energy by creating a 'level-playing field' through rationalisation of pricing, etc.

Thrust areas for international assistance

International funding can play a major role in the rural energy sector by facilitating alternative approaches. Given below are some of the areas where this could be done.

Programme planning and implementation

Experience has shown that rural energy programmes can make a substantial impact only if they are in tune with the developmental priorities of the targeted people. These priorities are typically scarcity-driven and related to income, employment, economic upliftment and basic infrastructure. Hence, there is a need to take up an integrated planning approach wherein energy is treated as the key input to the overall development process.

The international funding could play a key role in promoting such an integrated approach to rural energy planning by supporting microlevel organisations involved in such efforts. Organisations should be identified and encouraged to take up integrated and decentralised planning. It is important to note that such efforts would require sustained

support and funding for a period of, say 5 years, before any results can be expected. A micro level geographical unit such as block, a cluster of villages, or watershed could be taken up for demonstration.

Energy conservation in rural industries is one area which has received scant attention so far, and there is substantial potential for investment in this sector. Usually, rural industries are situated in contiguous geographical clusters, and interventions would have enormous energy and environmental benefits.

Capacity building

Lack of involvement of local communities, especially women, in planning, implementation and follow up aspects of rural energy programmes has been identified as an important reason for the inconsistent performance of these programmes. The main reasons for this poor participation are a lack of effective planning software and mechanisms, and an inadequate human capacity at the grassroots level. It is increasingly being realised that if local communities are to contribute significantly and find sustainable solutions to their environment and energy related concerns, there is an immediate need to build capacities at the grassroots level in terms of creating awareness regarding energy and environment issues, and developing technical and managerial expertise to plan and manage programmes effectively.

Although the requisite planning skills may be absent in the local communities, there are a large number of organizations and institutions in various parts of the country working in these sectors and there is a wealth of experience available. There is also a great deal of indigenous knowledge and understanding of the local resource systems which is often not made use of effectively in rural energy programmes. However, there is clearly a need to bring about a coordination in these efforts and communicate these with a larger audience.

An effective strategy for facilitating a process of local capacity building would be to integrate these experiences and utilise the existing knowledge base and expertise to impart training to a larger target group. This can be achieved by establishing and strengthening a network of organisations working in these fields.

The thrust of international assistance in this area should be to develop models for facilitating local capacity building by promoting institutions at regional levels which would take this up for identified target groups including government functionaries, non-governmental organisations, village level institutions, women and the rural population at large.

Information dissemination

As mentioned earlier, there is a wealth of experience available at various levels in planning and operational aspects of rural energy. However, the exchange of this exchange is not very effective in absence of coordinated efforts. Therefore, internal funding could be provided for developing information packages (print as well as audio-visual) on various rural energy programmes and technologies to cater to different interest groups. Similarly, programmes could be assisted to conduct periodical conferences and workshops, at state, national and international level, highlighting the experiences and the latest developments taking place in the sector.

Research and development

While a number of technologies are available for meeting rural energy requirements, some of them need to be developed further to attain techno-economic viability. Some technology development is also required to expand the resource base. A select list of priority R & D topics are discussed below:

Alternative feedstocks for biogas production

Presently, biogas is dependent on cattle dung alone which limits its potential. If alternative feedstocks are developed, the potential for biogas could become unlimited. Therefore, funding could be considered for studying the microbiological aspects of biogas production. Another area of priority is to develop bacteria cultures which could work under low temperatures and water scarce conditions, which could enhance the spread of biogas considerably. High rate biogas reactors is another area of importance.

Low-cost fuel-efficient cookstoves

Presently most cookstoves are made in mud or with metal, and a number models are available in this. However, there is scope to develop stoves with other material (eg. ceramics) which are low cost but have high durability.

High capacity gasifiers for power generation

Presently gasification technology is confined to small, mainly thermal applications. There is a need to technology development work to design higher capacity systems for larger applications. Such projects could also be combined with afforestation projects to ensure sustained supply of biomass.

Solar Thermal systems

Technology development work in this area can bring about cost reductions in systems like solar cookers, water heating systems, etc.

Session V

Rural Energy Planning

All aspects of rural energy planning have been discussed in this session. The aim of this session is to make the participants aware of the various steps in formulating a rural energy plan. The importance of issues like developmental priorities of the people in formulating an effective rural energy plan has been highlighted. A few planning exercises carried out by TERI have been discussed.

Contents

- Selection of project unit
- Secondary information
- Consumption & demand estimation
- Supply assessment
- Study of development priorities
- Techno-economic assessment
- Assessment of environmental benefits
- Development of plan & strategy
- Examples of energy planning exercises

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Rural energy planning

Introduction

While formulating a methodology for rural energy planning it is important to understand the purpose and the extent of intervention in the rural sector. In this methodology, the aim of such intervention is to develop workable options in the existing energy system which mirror the more urgent energy needs of the people and where immediate attention is required (this may be a part of the energy system or a geographical cluster). The emphasis is to conduct primary data collection to supplement the secondary (existing) data and to rely on local knowledge. With this approach, the implementation of the interventions are likely to be values by the beneficiaries and they also incorporate judgement of local officials entrusted with the task of implementing programmes in the region. Furthermore, implementing programmes intensively in geographical clusters makes it much easier to plan and provide for manpower, spares, etc. for an effective post-installation maintenance, and aspect missing from most programmes. Apart from these advantages, there is another, more pragmatic, consideration in favour of this approach which is that the government-sponsored interventions in the rural energy sector could, at best, play only a catalytic role. Logically, therefore, all rural energy programmes should be directed where the chances of success are the highest rather than to spread out too thin. Regions requiring interventions would correspond to areas where energy (or the lack of it) is the felt need of the people or where development of local energy resources can influence the economic situation in the area favourably. Thus, decentralised planning appears logical in the context of rural energy planning.

Decentralisation in rural energy planning

Decentralisation is being advocated in the interest of efficient utilisation of resources and for ensuring more equitable sharing of benefits from development. In addition to the general arguments in favour of decentralisation, there are some specific reasons to endorse decentralised rural energy planning. An important characteristic of rural energy system based on biofuels is its localised nature arising out of the localised nature of supply of biomass. This implies that the accounting (assessment of the demand and supply), and the intervention in the energy system which may appear desirable due to such an accounting, must be at a similar geographical scale. Biomass accounting at the aggregate level is likely to be misleading as it would not reflect the scarcity or surplus at micro level. Consequently, the interventions (which may take the form of supply

enhancement, containing demand and/or encouraging fuel switching) may be aimed at the wrong target group or area.

For overall development planning the level of decentralisation will be determined by socio-economic and political factors, whereas for rural energy planning specific characteristics of the rural energy system will also have a bearing on the desired level of decentralisation for effective planning.

In the context of energy planning, currently, decentralisation exists at block level in the form of Integrated Rural Energy Planning (IREP) Programme being coordinated by the Energy Cell of the Planning Commission, and village level in the form of Urjagram projects being coordinated by the Ministry of Non-conventional Energy Sources (MNES). However, the upward integration with energy and general developmental planning, and the pivotal role of the district in the existing administrative structure, manpower availability and the nature of the biomass supply system would warrant planning from the district but implementing interventions from the Block (or some other existing intermediate administrative level between the district and the village). This appears to be the most promising combination in the Indian context.

Also, in absence of reliable methods to determine the biomass (or system) boundaries, physical parameters will have to be used to demarcate the boundaries. Thus, contiguous villages with a particular characteristic within a radius of 10 km will form a cluster-of-villages. Going by the earlier classification of physical limits of distances through which biofuels can be moved (in the range of 5–10 km), the number of villages in the cluster would vary sharply (depending on the average area of each village). in the present approach, programmes are formulated at the cluster-of-villages level.

To sum up, specific intervention programmes/projects formulated for the cluster-of-villages level will be planned from the district and implemented from the block. This is the essence of the methodology proposed here for rural energy planning.

Approach

A district rural energy plan would typically consist of:

1. estimating, projecting and comparing the energy demand and supply for a certain time frame (e.g. period covering a Five year Plan) based on demand estimates and resource assessments aggregated at the block level;
2. identifying cluster(s) of villages requiring interventions(s);
3. suggesting cluster-wise cost-effective intervention plan incorporating the articulated development priorities; and
4. recommending a management strategy for implementing the energy plan.

In order to accomplish the above elements, the following procedural steps need to be followed:

1. collection and analysis of secondary data;
2. design of survey (determination of scope and extent of survey, selection of survey area, choice of survey method);
3. conducting primary surveys;
4. data compilation, validation and analysis; and
5. preparation of energy plan including management strategy for implementation.

In subsequent sections for each element in planning the procedural steps are explained. In the annexure, some sample questionnaires have been given.

Secondary information

Secondary level information serves the planning exercise in several ways:

(a) Firstly, it enables development of a profile of the area to be planned (district, in this case) in order to provide a broad understanding of the demographic, geographic, socio-economic and eco-cultural aspects which might have a direct or indirect influence on the energy system in the district.

For instance, a typical district profile compiled from different secondary sources could contain the following items of information:

1. physiography (soil, water, landscape, etc.);
2 Climatic indicators (rainfall, temperature, etc.);
3. Demography (rural-urban population, literacy levels, categories of workers, etc.);
4. Landuse pattern (lan categories, ownership pattern, etc.);
5. Agriculture (main crops, land under different crops, extent of irrigation, crop yields, fertiliser use, etc.);
6. Livestock data (bovine population, milk production, dung yields, etc.);
7. Infrastructure (status of roads, market penetration, electrification, social amenities, etc.); and
8. Energy system (fuel mix-enduse matrix, existence of formal distribution networks, etc.).

(b) Secondly, the information would provide an insight into the energy system itself, in terms of resource availability to meet the energy needs. For instance, perusal of the records of Forest Department could give information on fuelwood extraction; livestock data could provide an estimation of cow dung available; information on

PDS could give insight into the supply system of commercial fuels, and so on.

(c) Secondary information would help in understanding the development strategy adopted by different government departments, budgetary allocations for different activities including energy interventions, etc.

(d) Finally, analysis of secondary level information will form the basis for determining the scope, magnitude and methodology for the different primary survey(s) to be conducted. For instance, as will be shown subsequently, the village level information on landuse pattern available from the District Census Handbook could be the basis for selection of sample villages to be surveyed for assessing the biomass availability and estimating the energy demand.

Therefore, it is necessary to collect secondary level information as exhaustive as possible so as to minimise the efforts in other components of the planning. Usually, secondary information is available from a variety of sources at the village, block, district, divisional, and state levels. The extent to which information collection could be done is determined by the time and resources available for a particular exercise. A list of sources from where the secondary information will be available is given below:

Sources of secondary information

Source	Information	Likely source organisations
District Census Handbook	Village-wise information on landuse, demography, and occupational and infrastructural indicators	Census Department of State Capital, District library, District planning/statistical Department
Power statistics	List of electrified villages, no. of energised pumps, electrification schemes, loads at substations, etc.	District office of State Electricity Board (SEB)
Village level energy surveys	Data on past energy consumption pattern in the district/region	District/state offices of state nodal agencies for energy programmes
Handbook on Agriculture	All the agricultural statistics at district level	Agricultural Department at district/divisional level
Records of Forest Department (working plans, annual plans, etc)	Statistics on forest resources (fuelwood and timber production, movement, rate of extraction, illegal fellings, etc.)	Divisional forest offices at district level, circle office at divisional level.
Statement on supply of commercial fuels	List of kerosene dealers, petrol pumps, supply and consumption, etc.	District Food Department, District Magistrate, state/divisional office of oil companies.
	Livestock statistics	District veterinary Department, Animal Husbandry Department
Annual plans	Information on developmental activities, their budgetary allocations, schedules, etc.	District Magistrate/District Planning office/state Planning Board
Rural credit plans	Credit allocations for different activities, potential for different development projects	NABARD office at state capital/lead bank at district headquarter/district magistrate
District Gazette	History and evolution of the district, natural resource base	District Magistrate/Library
District maps	Topographical information (contour, forest cover, water bodies, etc)	Survey of India sales office at state capital/regional centres
Hydrogeomorphological maps	Groundwater potential in the district	Public Health Engineering Department, Groundwater Department, Irrigation Department offices at the District Headquarter
REC maps	Location of electrified villages, extension of grid lines	District office of SEB
Block maps	Location of villages in a block	Block Development officer

Energy supply assessment

In order to design an energy intervention plan for the region it is necessary to understand the present energy consumption pattern and the various sources contributing to the energy mix. Usually, biomass fuels account for most of the rural energy needs, and therefore it is imperative that a proper assessment of biomass supply is made. At the same time, learning the extent of the use of commercial fuels is also important as they are often critical for certain end-uses (e.g., lighting and irrigation). A typical fuel-end use matrix in rural areas will look like this:

	Cooking	Water heating	Space heating	Lighting	Motive power	Appliances	Transport
Fuelwood	X	X	X				
Crop waste	X	X	X				
Dung	X	X	X				
Kerosene	X	X		X			
LPG	X	X					
Diesel/petrol					X		X
Electricity	X	X	X	X	X	X	
Coal	X	X					

Depending on the local use and resources, specific fuels can be chosen for assessment in a particular district. However, given their predominance in most rural areas in India, biomass resources to be considered are woody biomass, animal dung and crop residues while kerosene, electricity and diesel are important among the commercial source.

Energy demand estimation

The approach for demand assessment described here, as opposed to the traditional approach of merely studying the supply and use of primary energy, puts more emphasis of end-uses and looks for optimal energy conversion routes to meet these end-uses. This allows flexibility in identifying suitable fuel-mix for different end-uses, and may lead to an energy policy that distinguishes between energy for subsistence and energy for economic development.

The first step in the process of demand assessment is the design of a survey to collect information on the present energy consumption pattern. However, given the mandate of preparing an energy plan to meet the energy demand for subsistence as well as

development and designing a suitable management system, the survey should go beyond energy consumption to include the following:

a) getting an idea of the local energy and development issues;
b) getting an idea of the existing energy situation in different blocks; and
c) finding the potential of different energy sources and their possible relevance for the development process of the district

Sample selection

Again, a representative sample of villages needs to be selected to conduct the primary survey. The following criteria, which reflect the availability of biomass energy, could be used as the basis for sample selection:

a) per capita forest land
b) per capita agricultural land
c) per capita culturable wasteland
d) per capita bovine population

In absence of above information, alternatively following secondary information can be used for sample selection:

a) accessibility from road
b) infrastructure available in the villages (like school, health centre etc.)
c) population

In the recent past, all the energy surveys done by TERI uses a combination of these criteria for sampling, and sampling is done in such a way that the villages identified for energy surveys are true representative of the total population.

Survey instruments

In order to conduct the survey, structured questionnaires could be designed with two components - village schedule and household schedule. All the information pertaining to the village as a whole will be covered in the village schedule while the latter will be more specific to the individual household. [A typical questionnaire has been presented in the appendix for reference.] However, it is useful to first conduct a pilot survey in a few villages to determine the efficacy of the questionnaire used. Based on the feedback from this, it could be changed to be used in the primary survey.

Data analysis

To arrive at the energy consumption pattern in the district, the following procedure could be adopted:

(a) Data on all the variables for which information is collected can be compiled on master sheets ensuring there are no ambiguities. The survey data should be separated and compiled according to blocks. Computerizing the data will facilitate the analysis described below. The variables pertaining to energy consumption are the most relevant for estimating energy demand for different end-uses. Particular attention should be paid to cooking, lighting and irrigation, which are usually the principal end-uses in a rural energy system.

(b) **For cooking and other thermal energy use:** Once the data has been compiled according to the blocks, the average per capita fuel consumption for different fuels should be calculated and compiled.

(c) **For lighting and motive power:** The block-wise compiled data is then used to compute the (1) average *house hold* fuel consumption for lighting and (2) fuel used *per hectare* (or acre) for irrigation and compiled.

(d) Using the consumption figures from the above two steps, the block level of aggregates for the different fuels for different end-uses can be computed. For thermal energy requirements, the census population for the Block should be used. For lighting and irrigation, the Census report (or any other source) for the number of households and the total irrigated land in the block, respectively, can be used. These can be summed for all the blocks to give the average for the district.

(e) Using the projections for population (from which the number of households can also be calculated) available from the Census data (if ready projections are not available, they can be computed with the help of the population growth rates given the Census), the above steps can also give the projected energy demand for the time frame for which the energy plan is to be prepared. These would constitute the *base case scenario.*

(f) To examine the impact of energy interventions in different energy end-use sectors, different scenarios can be created. Such scenarios can examine the impact of, for example, substitution of non-commercial fuels (fuelwood, dungcake, agricultural waste) by commercial fuels (kerosene, LPG, coal etc.) wherever the end-use would permit.

Development priorities

If the objective of planning to meet the energy needs of the economic development has to be achieved, it is necessary to develop an understanding of the development process and

priorities of the people of the district. Part of the reason for the inadequate response to many development programmes can be traced to the a\divergence of perceptions between the people and the government officials of what the priorities of the region are. This difference in the perceived priorities. is of relevance to the response of the people to energy related projects as the level of integration of energy interventions with the overall development activity would determine their chances of success. Therefore, it is imperative to understand the priorities as perceived by the people who benefit as well as the government (officials) who implement the development programmes. Two main aspects that need to be studied are:

a) Priorities of the government
b) People's perceptions

It is clear that such a planning exercise reflects the priorities set for the district, including that of energy requirements. This would give an indication of institutional financing that is likely to be available for energy intervention programmes.

Energy plan

The basic objectives of an energy plan for the district could be

a) To propose a technology-mix to meet the energy demand, as assessed in the study, sector-wise and end use-wise;
b) To suggest specific locations for specific interventions including targets and budgetary requirements; and
c) To recommend energy interventions for specific development activities which require detailed feasibility studies.

In order to achieve these, the following guidelines can be adopted to formulate an energy plan:

(a) The guiding principle of the methodology proposed here is that *large scale* intervention to *radically* alter the existing energy system in the district, which is based on collected biomass (to which there are no cost-effective alternatives), has limited chances to succeed. Therefore, the short-term interventions should be directed to those areas and end-uses where the felt need is the strongest.
(b) During the sample selection process, village clusters with specific attributes are already identified. Since these clusters have uniform characteristics, they will be the appropriate unit for which interventions could be recommended. [These characteristics can be corroborated while doing the primary survey]

(c) The willingness of consumers to pay for the higher quality energy sources needs to be considered while working out various options.

Implementation

Is often the implementation process of energy plans that determines their success. so it is imperative that an appropriate management system be developed as an integral part of the energy planning exercise. The following steps could be followed in designing such a system:

(a) First of all, it is necessary to study the organizational functioning of the different departments/agencies currently involved in the energy programmes and related development programmes (energy nodal agency, DRDA, forest department, agricultural department, electricity department, etc.). This should be in terms of the organizational structure, responsibilities of specific programmes, the adequacy of staff involved in implementation both in numbers as well as capabilities. etc.

(b) It is also important to study the linkages among various agencies involved in energy programmes so as to estimate the level of coordination.

(c) The analysis of inter- and intra-agency functioning will provide an idea of the efficacy of the existing implementation structure. This can be used to identify an organisation/department that can act as the coordinating agency for implementing the energy plan.

(d) Such an agency will act as the 'link-pin' agency which would interact with various organizations to be involved in the implementation.

Energy planning studies

Energy Intervention plan for the rural domestic sector in selected blocks of Jodhpur district, Rajasthan

Objective

To prepare an energy intervention plan for the rural domestic sector in four blocks of Jodhpur district; Phalodi, Bap, Shergarh, and Balesar. Specifically:

- To estimate the domestic energy requirements in selected areas of the blocks;
- To study the availability of biomass and non-biomass resources in the selected areas;
- To estimate, in the light of supply and demand assessment, the potential of renewable energy technologies for specific interventions;
- To identify village clusters where specific technologies can be utilized to meet the energy requirements;
- To devise an energy intervention plan for the four blocks that can be implemented; and
- To suggest a management strategy for effective implementation of the intervention plan.

District profile

Jodhpur is one of the 11 desert districts of Rajasthan and falls in the heart of the Thar desert. Climatically, the area is extremely arid and dry and suffers from low and erratic rainfall, long dry spells and frequent drought. Jodhpur has a negligible vegetation cover. The only green patches that can be seen in the villages in this area are traditional "Oranas" or village forest lands.

Agriculture is an important occupation in the rural areas of Jodhpur. In years of normal rainfall, most farmers are able to take a single crop, i.e. of Kharif as agriculture is, almost entirely, rainfed. Dryland crops like Bajra, Jwar, Moth etc. are grown. In small pockets of the district, irrigated agriculture is practiced by large farmers who own irrigation pumpsets. Cash crops like mustard, chilies and wheat are grown in these pockets. Agricultural residues in this area are used for cattlefeed. Jodhpur traditionally has a livestock based economy. Mainly goats and sheep are reared. Most farmers who can afford it keep camels. Camels serve as local transport as well as beasts of burden. Ground water is scarce in the district. Because of poor and erratic rainfall, sandy soils and high

evaporation rates, the recharge is very low. There are very few natural sources of water like rivers, streams, ponds etc.

Approach

Given the overall objective, the project was broken down into the following components:

Energy demand estimation

The present energy consumption pattern was ascertained through a sample survey in the 4 blocks. The main objective of the village level survey was to assess the availability of various resources (like land-use pattern, drinking and irrigation water sources, livestock, fuel use and level of physical infrastructure).

Information collected

At the household level, questionnaires were administered to obtain information on present energy consumption pattern, per capita and total fuel consumption for various end-uses like cooking, lighting, and water-heating. In addition, information on awareness of the people regarding renewable energy technologies and willingness to adopt the same were also ascertained.

Resource assessment

Resource assessment was done primarily on the basis of secondary data available with various government departments.

For woody biomass

Information on number of trees on private fields was obtained by questioning the farmers. Acuteness of the fuel problem resulted in more accurate information from the villagers, which was adequate for the purpose of this particular study. Primary survey also yielded information on local tree species and their use. Other sources/methods that could be used for estimating the supply of woody biomass are:

1. *Working plans of the forest department*. This source could not be used in this study since there is practically no forest area in Jodhpur division.
2. *Vegetation studies using quadrate method*. This method is used for estimating the productivity of wastelands. In case of this study, the method could not be applied as the density of trees in some areas is as low as a single tree per *bigha*. Therefore, it was not feasible to mark out quardrates on the ground and measure the productivity of these.

For non woody (animal dung and crop residues) biomass

Primary survey was done to obtain the necessary information. In case of animal dung, availability was ascertained on the basis of average collectible dung rather than using the cattle population. This was necessary as most of the cattle is left for open-grazing and actual collectible dung is only a small proportion of the total dung produced.

Supply of commercial fuels

The supply of commercial fuels like LPG and kerosene in terms of price, distance from the nearest distribution point, availability, affordability, etc. were studied.

Potential of renewable

For studying the potential of renewable energy technologies like biogas plants, solar photovoltaic and windpumps for water lifting etc., availability of dung, groundwater and other sources of water were studied in detail. Data on solar radiation availability and wind speeds were collected for the purpose.

Energy plan and management strategy

The interventions were suggested at a cluster-of-villages level and implemented at the panchayat samiti level. Devising a suitable energy plan and management strategy involved:

Estimation of gap between demand and supply of energy sources

Once the energy demand and availability of energy sources were established, the gap between the two was ascertained.

Determining suitability of renewable energy devices

With the help of the primary survey, suitability of specific energy devices like biogas plants, improved chulhas and solar cookers to specific clusters of villages was gauged. The potential of energy plantations for growing fuel and fodder yielding species was also explored. The potential of wind and solar PV technologies for water-lifting was examined.

Understanding of the implementation strategy

An attempt was also made to understand the present implementation process and possibilities to strengthen the same.

Methodology

Given this overall approach, the study was carried out in a modular fashion. The methodology that was adopted can be broken down into the following specific modules:

Secondary data collection

An extensive collection of the secondary information was carried out at the national, state, district and panchayat samiti levels. This served the following purposes:

(i) provided an understanding of demographic, geographic and socio-economic aspects of the area, thereby helped to build a profile of the study area;

(ii) the secondary information also helped to identify villages for the primary survey; and

(iii) the data was also used for assessing the resource availability in the area and potential of different renewable energy technologies.

Table 1 presents the kind(s) of secondary data collected for the study and the corresponding sources;

Table 1. Secondary data & sources

Data	Source
Basic statistical data for the villages	Census Department
Village-wise data on livestock population	National Informatics Centre, Jodhpur
Crop related data (area under crops, productivity etc.)	Tehsil offices at Phalodi, Shergarh and Balesar
Information on biomass productivity	Forest Department, Jodhpur
Government afforestation programmes, species grown, traditional forest management practices etc.	School of Desert Science, University of Jodhpur and Central Arid Zone Research Institute (CAZRI), Jodhpur
Information on consumption of kerosene and kerosene depots under PDS	Civil Supplies Department, Jodhpur
Information regarding the present programmes for rural development, especially biogas technology dissemination and Improved chulhas	District Rural Development Agency, Jodhpur and Zila Parishad office, Jodhpur
Information on solar devices	CAZRI, Jodhpur
Resource maps depicting soil types, vegetation, water resources, etc	State Remote Sensing Application Centre, Jodhpur
Data on solar radiation availability and wind speeds	Solar and Wind energy directories of India
Information on study area, programmes, potential of renewable sources, local development priorities etc.	Non Government Organizations

Primary data collection

A survey was designed to collect information on energy consumption pattern, local resource availability, development priorities of people, peoples' perceptions and scope of

renewable energy technologies. A sample survey was conducted in 26 villages covering 292 households. Schedules were administered at village and household levels.

Sample selection

Secondary data was analyzed to arrive at a short list of villages in each panchayat samiti. The secondary data was analyzed in the following manner:

- A set of parameters was identified which influence the energy consumption pattern at the village level.

Table 2. Parameters influencing energy consumption

Parameter		Purpose
Cultivated land per household	0-15 ha,10-20 ha, 20 ha	Indicates income, biomass availability on private fields
Cultivatable wasteland	0-100 ha,00-500 ha, > 500 ha	Indicates potential for energy plantation
Cattle holding per household	0-2, 2-5, > 5	Indicates potential for biogas plants, income
Infra structural facilities	distance from nearest town, electricity for domestic connection kerosene depot, motor able road	Indicates access to commercial fuels

- All the 297 villages falling in the four panchayat samities were classified into three categories on the basis of each of these parameters.

Table 3. Categories for village selection

	Low	Medium	High
Cultivated area per household (ha)	0-10	10-20	>20
Total culturable wasteland (ha)	0-100	100-500	>500
Infrastructure	0-2	2-4	>4
Cattle per household	0-2	2-5	>5

- A sample of villages were selected randomly from the above identified 12 categories.

Survey instruments

The survey instruments used in the study are:

Table 4. Survey instruments

Survey tools		Information obtained	Sources
Questionnaires	Village	land use, cropping pattern, biomass availability, fuel use, government programmes, development priorities etc	Village elders, panchayat members, school teachers etc
	Household	family composition; literate members; occupation; resources owned: land, livestock; fuel consumption and cooking practices; fuel collection; sources; etc	Individual household members
Participatory research approach (PRA)	Priority ranking	preferences for: tree species, fuel type etc	Groups of men and women
	Resource mapping	location of different communities within the village, water sources, forested area etc	
Diagrams & measurements		diagrams of cooking devices, weight of fuelwood consumed, dungcakes etc	
Energy flow		Flow of energy sources taking a village or household as a unit	Groups and individual household members

Data analysis and devising of the plan

Once the primary and secondary data was collected, it was compiled and analyzed. Data analysis yielded useful information on biomass use, limitations of commercial fuels to meet the demand, and feasibility of various renewable energy technologies in the study area.

Devising of energy plan

Assessment of potential for various renewable technologies

An intervention package in the domestic sector can essentially be a combination of one or more of the following technology options:

Table 5. Technology options

Enduse	Technological options
Cooking	Biogas plants, improved chulhas, solar cookers, energy plantations
Lighting	Solar PV lighting
Water lifting	Solar PV pumps, wind pumps
Others	Solar dryers, solar stills, solar water heaters

Suitability criteria for each technology were identified and overall suitability for the area was determined. The intervention plan was devised at the cluster-of-villages levels. These clusters for each technology was identified on the basis of secondary data.

The above has been explained for determining the potential of biogas technology for the area:

(i) For installing family size biogas plant (say 2 cu m), a certain minimum quantity of dung is required to be fed daily (50 kgs/day). Accordingly, data on cattle holding per household was used for first shirt listing of villages for biogas plants.

(ii) Mapping of these villages was then done to determine the location of these villages. This exercise showed that the identified villages are located in clusters.

(iii) As water is a necessary input in biogas plants, information on water availability (ground water potential and quality, government water supply scheme, irrigation sources) was superimposed on the identified villages to further short list.

(iv) The final list of villages suitable for installing biogas plants and number of plants to be installed was arrived at by extrapolation of primary data collected in villages falling in similar topologies.

The total targets were phased out over a period of three years depending on level of infra structural facilities available. The potential for various renewable technologies was determined in a similar fashion.

Some important findings of the study include:

(i) Deenbandhu fixed dome plants are more suitable than KVIC plants due to it's lower cost and better insulation to withstand the large difference in day and night temperatures;

(ii) A simple design of the chulha is more desirable considering the lifestyles of the people and the inaccessibility of the area;

(iii) There is a good potential for solar technologies, especially for the end use of lighting, as the area receives maximum solar radiation and supply of grid electricity to the widely spread villages is very costly;

(iv) Wind pumps in the study area can only be used for meeting drinking water demands of isolated *dhanis* or small villages; and

(v) Energy plantations raised on wastelands could ensure the supply of biomass in a sustainable manner and thus help to enrich the resource base.

Designing energy interventions plans

After assessing the potential of different technologies for the area as a whole, clusters of villages were identified for the intervention plan.

Finally, these were crystallized in the form of year-wise targets, keeping in mind the following:

(i) the overall potential,

(ii) level of infrastructure facilities, and

(iii) the existing implementation network.

The technologies covered in the energy intervention plans designed as a part of this study can be divided into two broad groups:

Low investment technologies. The first group of technologies are those which that can be installed at the household level on a large scale. There is already a good deal of awareness regarding these. These are biogas plants and improved cookstoves.

High investment technologies. The high investment technologies include solar photovoltaic pumps, wind pumps, and solar lighting devices. Given the present level of awareness regarding these and available infrastructure, these should be implemented initially on a demonstration basis.

Important considerations

Some important considerations that went into the designing of the rural energy intervention plan for the area are:

Linking energy interventions with development priorities

For the success of any intervention programme, be it household energy or any other, it is imperative that it is accepted well by the people. This can happen only if the intervention is in line with the priorities of the people, i.e. it addresses one or more of the felt needs. Therefore, there is a need to understand the development priorities in general, and people's

perception regarding energy problem and link energy interventions with these development priorities. Further, no problem can be treated in isolation. For instance, if fuel is scarce in the region resulting in a demand for biogas; the option is still not feasible if there is no sufficient water.

Need to look for renewable energy options

The need to look for renewable sources of energy for the area stemmed form two factors: (i) An acute stress on biomass resources, and (ii) Limited reach of commercial fuels due to poor accessibility.

Enriching biomass resource base

It is important to note that any technological intervention in the domestic energy sector can only serve as a short term solution. The problem is really that of an already scanty biomass resource being over stressed because of an increasing population pressure and their demands of fuelwood. Thus in the long run, there is a need to augment fuelwood supply through enriching the biomass base.

Cluster approach

For renewable energy technologies, a cluster approach should be adopted. This means that instead of carrying out interventions in isolated villages, careful planning should be done to take up of clusters of adjoining villages at a given time. This would: (i) lower the cost of implementation. (ii) facilitate better monitoring, and (iii) better back up and maintenance services can be provided.

Implementation of energy plan

The major constraints identified in the implementation of the rural energy plan in Jodhpur are:

Inadequate infrastructure

The villages in Jodhpur are far flung and spread out. The infra structural facilities in the region are very poor resulting in low employment opportunities and hence low standards of living. All these factors add up to increase the cost of any intervention. Discussion at panchayat samitis indicated an acute shortage of staff. Another fall out of a poor infrastructure is the limited access to kerosene and electricity.

Lack of repair and maintenance support

This is another major fall-out of a poor infrastructure. Findings of the study indicate a grossly inadequate maintenance and follow up system for the energy devices installed in the study area.

Multiple agencies looking after different technologies

It is common to fine a large number of organisations promoting various programmes/activities at district/block level. For example, at the district level you have the DRDA promoting biogas and the Zila Parishad responsible for Improved chulhas. This multi agency approach causes problems in co ordination.

Inadequate training

In the installation and maintenance of RETs, it is important that field level functionaries are suitably trained. In areas like Jodhpur where villages are located far from each other, training local people in maintenance of the devices would ensure their sustainability.

Financial implications

Broad investment requirements for the proposed intervention plan were worked out by calculating the average unit cost for each device taking into account the rate of inflation. Total investment requirements for these will vary in direct proportion with the number of units installed. The unit costs will also vary with the area as it is dependent (in some cases) on variables such as transportation costs.

Rural Energy Plan for Changlang district, Arunachal Pradesh

Objective

To prepare an energy intervention plan for Changlang district.

- To meet the objective the study has followed four distinct work components, namely:

(a) Collection of secondary data and identification of planning zones;
(b) Energy demand estimation by sample survey in selected villages;
(c) Energy resource assessment with the help of secondary information; and
(d) Energy plan and implementation strategy at the block level.

District profile

Changlang district was created after the division of erstwhile Tirap district in 1987. The district consists of 10 circles covering 286 villages. The district is located between the latitudes 26°40'N and 27°40'N and the longitudes 95°11'E and 97°10'E. Changlang district is bounded on the East and South by Myanmar. Tirap district and Dibrugarh district share the South-west of the district boundary. Lohit district lies in the North of the district. The total area of the district is 4662 sq.km. and the population of the district as per the 1991 census is 95,530. Tribals constitute more than two-third of the total population and the main tribes of the district are *Tangsa, Tutcha Nocte, Singpho, and Millang*. Apart from these, *Chakmas*, *Tibetans*, *Nepalese* and people from the plains constitute the district population. The foothills area adjacent to the plains of Upper Assam and Lohit district comprise the main paddy growing area of the district, while the rest of the district is marked with hilly terrains and dense forests. Rivar Tirap and Nao-Dihing are the main rivers in the district.

Approach

The approach for the study has been to use the secondary information for resource assessment and primary surveys for demand estimation. An assessment was carried out on the availability of woody biomass, animal dung and crop residues. Estimates of commercial sources - kerosene, electricity and diesel were made. Based on the energy supply and demand, an intervention plan has been prepared which is specific to the area and utilizes the available resources in the district. Feasibility of different renewable energy technologies has been considered for the effective implementation of the energy

intervention plan, and an implementation strategy for the period 1995-2002 has been suggested.

Methodology

Planning zones

The district was divided into four distinct planning zones using the criteria of a) Physiography (Landuse), b) Livestock population, and c) Agricultural production (Paddy) as these parameters would reflect the energy consumption pattern in the district. Mean and standard deviations were obtained of the data available and the district was divided into three levels of low, medium and high. Based on these combinations different planning zones have been identified which are as follows :

Planning zone	Administrative boundary	Characteristics
I	Changlang, Miao and Jairampur sub-divisional headquarters	Administrative centres.
II	Bordumsa, Diyun and Miao(partly)	Plains and rich in agriculture.
III	Khimiyang, Changlang, Manmao and Nampong	Hilly terrains.
IV	Vijoynagar	Hilly area and isolated from rest of district.

Sample selection

Census information was the only information available for all 286 villages in the district and using this information villages were classified into three categories of settlements - first, second and third order settlements.

Population (Villages)	Settlement Order
Below 300 (207)	Third - III
300 - 1500 (68)	Second - II
Above 1500 (11)	First - I

Energy resource assessment

Growing stock and sustainable yield was calculated using the secondary information and analysed through computer based Geographical Information System (GIS). The supply scenario of commercial fuels was studied using the secondary information.

Fuelwood - Sustainable yield (1994)	2818314 tonnes
Kerosene (1994)	972 kilolitres
Electricity (1994)	6,960,720 Kwh

Demand estimation

Present consumption and projected demand was done using the per capita annual consumption figures obtained from the primary survey. The total electricity consumption was estimated by using the list of electrified households and per capita annual consumption values. Rest of the households in the district were assumed to be consumers of kerosene and the total consumption was obtained using the per capita annual consumption values. To estimate the demand for electricity it was assumed that there would be 10% increase in the number of electrified households by 2002.

Planning Zone/ Fuel	Electricity (000 Kwh)		Kerosene (Kilolitres)		Fuelwood (Tonnes)	
	1994	2002	1994	2002	1994	2002
II	84	129	207	319	131921	186173
III	2393	3681	138	212	58405	82425
IV	52	98	42	29	8822	12452

Energy plan and strategy

Based on the findings of the survey and using GIS, intervention plan for district was made. Implementation strategy has been prepared keeping in view the existing scenario in the district. Targets and investment worked out for different technologies has been given in the following sections.

RET's considered in the plan

System	Application	Replacement
Improved Chulha	Cooking	Fuelwood
Biogas Plant	Cooking, Lighting and Manure	Fuelwood, Kerosene
Solar Cooker	Cooking	Fuelwood, LPG, Kerosene
Solar Water Heater	Institutional (Hospitals)	Electricity
Solar Photovoltaic	Lighting, electricity, water pumping	Fuelwood, Grid Electricity, Kerosene
Gasifiers	Industries (Saw and Veneer Mills)	Diesel
Micro-hydel	Industries, Households, Agriculture	Fuelwood, Diesel, Kerosene

Improved chulha

Two models of improved chulha - AP and Khirmey are recommended for implementation in the district. The target areas for implementation of AP model are the plains -Bordumsa, Diyun and Miao. Khirmey model is recommended in the hilly areas of Manmao, Nampong, Changlang, Khimiyang and Vijoynagar, as this model has provision for space heating.

Biogas plants

In the proposed plan, FLXI model of biogas plant (1 m^3 capacity) is recommended to be implemented mainly in the plain areas of the district. Though other regions like, Changlang etc. satisfy the criteria for inclusion, they had to be excluded because of their relatively low potential.

Solar thermal technologies

As part of the implementation plan solar cooker is recommended for implementation in the households of three administrative centres - Changlang, Jairampur and Miao. Solar water heating systems are proposed to be installed in the hospitals of all the circle headquarters, and in the next stage hostels and other institutions are proposed to be covered.

Solar photovoltaic systems

SPV systems are proposed for remote villages which are not electrified and where chances of extension of electricity grid are low. As part of SPV plan two systems are proposed -

(a) SPV centralized system which can be implemented if there exists an organisational set up in the village or possibility of forming a co-operative to maintain the system and b) SPV home systems, where domestic kits are proposed.

Biomass gasifiers

A large quantity of biomass residue is available in plywood industries. This biomass residue can be gasified and producer gas can be used in boilers for steam generation, and in DG sets for electricity generation. Preliminary calculations indicate a potential for excess electricity generation after fulfilling all the thermal and electric energy needs of plywood industries. To design the gasification system, preliminary energy audit of all the plywood industries will be required.

Mini-micro hydel projects

Arunachal Pradesh has the largest number of small hydro power projects under operation in the region. In the present study, ten sites have been identified from the data provided by the Rural Works Department and using the Geological Information System - Arcinfo. These sites are indicative of the potential existing in Changlang district. Of the ten sites, two have been selected for implementation in the first phase i.e., the plan period. It is proposed that one of the sites should be grid-connected (Renuk - 1000 Kw), and the other be non-grid connected, stand-alone system (Daragaon/Vijoynagar - 100 Kw). It is recommended that detailed feasibility study of these sites should be done and for Renuk site it is proposed that the nodal agency should monitor its performance, while for the Vijoynagar local people should be trained.

Consolidated budget

The following table summarizes the number of systems proposed for implementation and the total investment required. Funding agencies like MNES, NEC, IREDA, etc., provide subsidy or soft loans for promotion of these technologies, and these can be approached for funding these projects.

System	Number of systems	Investment (in Rs.)
Solar water heater	10	5,89,000
Solar cooker	605	6,05,000
Improved chulha[1]	1465	6,40,000
Biogas plant	510	5,60,000
Solar photovoltaic plan - I	11	68,40,000
Solar photovoltaic plan - II[2]	318	82,55,000
Biomass gasifier[3]	12	1,19,60,000
Mini-micro hydel projects	2	7,30,00,000
		9,41,94,000
		9,56,09,000

[1]Of the total potential indicated, 1290 are AP model and 165 are Khirmey model.

[2]SPV plan - II includes 242 SPV domestic kits, 65 SPV street lights and 11 SPV systems for TV sets.

[3]The investment cost of Gasifier system includes Rs.2 lakh for energy audit to be conducted in plywood industry.

Session VI

Survey Techniques — I

Survey of the target area/ region forms an important part of the rural energy panning exercise. In this session various techniques of collecting information from secondary sources have been discussed. The participants will be familiarized with the different sources of secondary information and analyzing techniques of the data collected. Demonstration of a rural energy database, compiled by TERI, has also been planned in this session.

Contents

- Development of norms/indicators
- Reference energy systems
- Rural Energy Data Base

Survey Techniques

Normative techniques

Survey and planning can be done in two ways. One approach is to use the secondary data available from some syndicate sources. Second approach is to do primary survey, collect the data from the field, compile the data and do projections, to estimate the present energy consumption pattern and also the demand in future. Depending upon the time constraint and the budgetary constraint, either of the approaches can be adopted.

This section deals with the two approaches of the normative techniques, one is called Reference Energy Systems, and the other is use of the syndicated information or the on-line data.

Reference Energy Systems (RES)

Reference energy systems is a rural energy model specifically made for a region or for agro-climatic zone. It basically has three components - source, transformation, and enduse. RES is represented graphically to indicate the nature of energy flow that will take place from the source. the transformation that the source will go through and the enduses for which it can be used. Let us take for example, Kerosene as a source, and understand the nature of transformation and the enduses for which it can be used.

Source	Transformation	Enduse
Kerosene	Kerosene stove	Cooking
	Improved Kerosene stove	
	Pressured Kerosene stove	Water heating
	Kerosene lamp	Lighting
	Petromax	
	Dhibri/diya	
	Hurricane lantern	

Figure 1. Typical example of RES in rural areas

Once the RES model for each fuel or each end-use is prepared, the efficiency of each transformation process is collected, the quantity of source consumed is recorded, and using these information the consumption pattern of different fuels is calculated. One of the

major limitation of RES model is that, in India rural energy consumption pattern is very location specific. As a result of this, generalisation over a larger region or for a agro-climatic zone, though possible but would not generally hold true. The RES model, at best, can be used is to identify the general trend of the energy consumption pattern. and based on that an approximate estimation of the energy consumption pattern can be done.

Syndicated source

Syndicated source is another way of doing the energy planning. Generally the syndicated sources are the reports of IREP surveys or survey of energy consumption pattern done by some independent agencies. The problem with these types of sources is that, they are generally not complied and collated properly. Given this background a database was developed in 1992 which compiled the survey conducted by different agencies, state nodal agencies, and surveys done under IREP programmes, in one database, called Rural Energy Database.

Rural Energy Database (REDB)

REDB is a village level database, and is a compilation of energy surveys carried out between 1985 and 1992. It is a database of 708 villages across 14 agro-climatic zone. When the database was developed it was realised that there was a lack of quantative understanding of the variability in rural energy data, and there was no access to data, as these were not compiled. It was this need for compilation, access and ease of analysis of data, which resulted in this database. The database includes information of 57 variables. These variable can be broadly classified as data on - general features; land details; asset ownership; prices of fuels; domestic energy consumption pattern; and other data related to industries.

REDB can be used for the following applications:

- to identify regional variations in the energy consumption pattern, energy resource base, etc.
- to arrive at regional norms for energy consumption pattern
- to do demand forecasting
- to prepare energy intervention plan

REDB is continuously updated with the energy surveys done by the different agencies. At present it has data of 708 villages, and is likely to have data of nearly 800 villages by the end of this year. The following section gives the result of the data of 628 villages and

the results of the data analysis is given in tables 1 to 12. This is followed by list of the variables in the database.

Table 1. Extent of information provided in survey reports

Information item	Information provided	
	Yes	*No*
Land categories	398 (62.4)	240 (37.6)
Energy in agriculture	321 (50.3)	317 (49.7)
Animate energy use	272 (42.6)	366 (57.4)
Land ownership	499 (78.2)	139 (21.8)
Chemical fertiliser use	106 (16.6)	532 (83.4)
Crop yields	101 (15.8)	537 (84.2)
Seasonal variation in energy	50 (7.8)	587 (92.0)
Space heating requirements	45 (7.1)	592 (92.8)
Water heating requirements	131(20.5)	506 (79.3)
Prices of commodities	34 (5.3)	604 (94.7)
Village electrified?	429 (67.2)*	209 (32.8)

Figures in parenthesis indicate percentage of the total number of villages (638 villages surveyed)

* Except for the village electrification row, all rows describe whether the survey reports contained information on items in column one. The village electrification row indicates that the surveys covered in this study report 429 of the 638 villages (67.2%) as electrified.

Table 2. General features and infrastructure of the surveyed villages

Variable	Mean	Standard deviation	Minimum	Maximum	Number of observations
Population	1435	1881	11	22000	637
Number of households	248	330	3	4072	638
Distance from the main road (km)	4	5	0	30	492
Distance from hospital* (km)	6	9	0	65	256
Number of surveyed households	95	93	3	836	413
Percentage of households surveyed	60	30	3	100	413
Total number of schools	1.5	1.4	0	17	495
Number of wells	14	58	0	702	349
Number of handpumps	7	36	0	500	262
Number of electrified households	78	176	0	2600	522
Fraction of households electrified	0.3	0.3	0	1	522

* Hospital refers to a primary health centre.

Table 3. Land details of the surveyed villages

Variable	Mean	Standard deviation	Minimum	Maximum	Number of observations
Total area (ha)	935	2128	5	42383	495
Agricultural land (ha)	536	760	0	7869	538
Households owning land					
number	152	214	0	2441	523
fraction	0.7	0.3	0	1	523
Landless households					
Number	70	1338	0	1631	518
fraction	0.3	0.2	0	1	518
Total irrigated area (ha)	226	473	0	4638	413
Fraction of agricultural land irrigated	0.4	0.4	0	1	407
Per capita land area (ha)	0.9	1.7	#		
Per capita agricultural land (ha)	0.5	0.7	#		
Per capita miscellaneous land* (ha)	0.5	1.5	#		

* Miscellaneous land, as defined here, is all land other than agricultural land
Indicates that the value is less than 0.049

Table 4. Asset ownership in the surveyed villages

Variable	Mean	Standard deviation	Minimum	Maximum	Number of observations
Number of main* cattle	586	686	0	5900	597
Number of cattle (adults)	405	512	0	4400	374
Number of goats and sheep	354	970	0	15165	420
Number of other cattle	39	141	0	1463	178
Cattle population (per capita)	0.6	0.6	0	9	596
Number of electric pumpsets	20	53	0	530	416
Number of diesel pumpsets	8	18	0	154	372
Number of tractors	7	38	0	667	358
Number of threshers	10	45	0	667	257
Number of agro-industries+	1.4	2	0	24	385
Agro-industry primemover capacity (kW)	4.8	4.7	0	23	184

* "Main" cattle refers to cows, buffaloes, and bulls; "other" cattle refers to uncommon cattle animals such as camel, but does not include goat and sheep.
+ Agro-industry refers to rice mills, flour mills, oil mills and other agricultural product handling industries using motive power in its operation.

Table 5. Prices of energy resources in the surveyed villages

Variable	Mean	Standard deviation	Number of observations
Price of firewood (Rs/kg)	0.5	0.3	92
Price of dungcakes (Rs/kg)	0.3	0.1	50
Price of agri-residues (Rs/kg)	0.1	0.1	30
Price of kerosene (Rs/litre)	3.2	1.4	199
Price of diesel* (Rs/litre)	3.9	0.5	90

* The price of diesel in Delhi in December 1995 is about Rs 7 per litre; the Government administered price of kerosene in Delhi in December 1995 is about Rs 2.50 per litre and has been maintained at that level for several years by Government policy; In December 1995 the market rate (in place since March 1992) for 1 US$ was about Rs 35. In 1989 the average rate of conversion for the US$ was about Rs 17. The Rupee was devalued several times between 1991 and 1992 touching Rs 30 per US$ but remained stable in the range of Rs 30 to 32 to a US$ between 1992 and 1994. See *Economic Survey 1995/96*, Economic Division, Ministry of Finance, Government of India, New Delhi, India.

Table 6. Land and population details within agroclimatic regions

Zone#	Geographical Area (thousand ha)	Population density (per km²)	Net sown area* (%)	Forest Area (%)	Per capita cultivable land (ha)
1	245	62	18.2	45.3	0.20
2	274	118	18.7	42.8	0.19
3	69	692	63.8	11.0	0.10
4	164	526	62.8	8.7	0.14
5	143	466	70.1	4.5	0.17
6	116	331	80.9	3.2	0.27
7	395	136	35.9	35.2	0.32
8	370	137	45.0	14.2	0.45
9	331	170	59.7	11.8	0.40
10	395	200	48.4	17.1	0.32
11	197	321	43.3	18.7	0.18
12	117	441	37.2	29.0	0.12
13	196	175	51.4	10.9	0.36
14	175	58	47.7	1.2	1.31
15	8	29	4.2	88.1	0.21
Total/ Average	3195	215	47.0	19.3	0.26

Agroclimatic regions and numeric code

1.Western Himalayan zone; 2.Eastern Himalayan zone; 3. Lower Gangetic zone; 4. Middle Gangetic zone; 5. Upper Gangetic zone; 6. Trans Gangetic plains; 7. Eastern plateau and hills; 8. Central plateau and hills; 9. Western plateau and hills; 10. Southern plateau and hills; 11. East coast plains and hills; 12. West coast plains; and ghats; 13.Gujarat plains and hills; 14.Western dry regions

*: Net sown area is defined as the total agricultural land net of fallow land.

Source: Agroclimatic regional planning, *Yojana* (October 1-15, 1990): 4-6 (published by the Planning Commission, Government of India).

Table 7. Biofuel and kerosene contribution to useful domestic thermal energy (kcal or MJ cap/d) use (including water heating but excluding space heating) in different agroclimatic regions

Zone[a]	Biofuels							Including kerosene						
	Number[+]	Mean		95% Confidence Interval				Number[+]	Mean		Confidence Interval			
		kcal	MJ	kcal	MJ	kcal	MJ		kcal	MJ	kcal	MJ	kcal	MJ
2	15	1058	4.43	791	3.31	1324	5.54	15	1065	4.46	799	3.34	1332	5.57
3	4	1096	4.59	*	*	*	*							
4	30	459	1.92	379	1.59	538	2.25	28	466	1.95	367	1.54	566	2.37
5	1	551	2.31		0.00		0.00							
6	60	461	1.93	414	1.73	509	2.13	54	532	2.23	477	2.00	586	2.45
7	29	2115	8.85	1819	7.61	2412	10.10							
8	33	579	2.42	479	2.00	680	2.85	33	722	3.02	425	1.78	1020	4.27
9	82	672	2.81	627	2.63	716	3.00	64	719	3.01	656	2.75	782	3.27
10	4	892	3.73	*	0.00	*	0.00	3	1151	4.82	*		*	
11	41	1749	7.32	893	3.74	2604	10.90	8	400	1.68	*		*	
12	10	639	2.67	516	2.16	762	3.19	10	732	3.06	592	2.48	872	3.65
13	35	562	2.35	503	2.11	620	2.60	27	654	2.74	568	2.38	740	3.10
14	22	516	2.16	417	1.75	616	2.58	21	525	2.20	421	1.76	629	2.63
Total	366	848	3.55	736	3.08	960	4.02	263	647	2.71	597	2.50	697	2.92

Table 8. Fuel mix for meeting domestic thermal (including water heating but excluding space heating) energy requirement (fraction of total)

Zone#	Firewood				Dungcake			Agricultural residues			Fraction of kerosene in total energy			
	Number+	Mean	Confidence Interval		Mean	Confidence Interval		Mean	Confidence Interval		Number+	Mean	Confidence Interval	
2	15	0.74	0.59	0.88	0.06	0.01	0.11	0.20	0.08	0.32	15	0.01	0.00	0.03
3	4	0.52	*	*	0.22	*	*	0.26	*	*				
4	30	0.42	0.34	0.49	0.35	0.26	0.43	0.24	0.20	0.28	28	0.11	0.03	0.18
5	1	0.24	*	*	0.74		*	0.03	*	*				
6	60	0.31	0.24	0.37	0.39	0.34	0.44	0.30	0.24	0.36	54	0.11	0.08	0.14
7	29	0.97	0.94	1.00	0.00	0.00	0.01	0.03	0.00	0.06				
8	33	0.54	0.45	0.62	0.32	0.25	0.38	0.15	0.10	0.20	33	0.07	0.02	0.13
9	82	0.64	0.60	0.68	0.08	0.07	0.10	0.28	0.24	0.31	64	0.06	0.04	0.07
10	4	0.52	*	*	0.17	*	*	0.31	*	*	3	0.05	*	*
11	41	0.64	0.55	0.72	0.17	0.10	0.23	0.19	0.13	0.26	8	0.03	*	*
12	10	0.88	0.81	0.96	0.09	0.02	0.16	0.03	0.02	0.04	10	0.13	0.12	0.14
13	35	0.68	0.60	0.77	0.15	0.10	0.21	0.17	0.09	0.25	27	0.10	0.04	0.16
14	22	0.48	0.34	0.63	0.42	0.31	0.54	0.10	0.04	0.15	21	0.00	0.00	0.00
Total	366	0.58	0.55	0.61	0.21	0.19	0.23	0.21	0.19	0.23	263	0.07	0.06	0.09

Agroclimatic regions and numeric code: 1. Western Himalayan zone (insufficient data for inclusion in this table); 2. Eastern Himalayan zone; 3. Lower Gangetic zone; 4. Middle Gangetic zone; 5. Upper Gangetic zone; 6. Trans Gangetic plains; 7. Eastern plateau and hills; 8. Central plateau and hills; 9. Western plateau and hills; 10. Southern plateau and hills; 11. East coast plains and hills; 12. West coast plains; and ghats; 13.Gujarat plains and hills; 14.Western dry regions

* Due to the small sample size, the 95% confidence interval has little significance

\+ Indicates the number of villages covered in this study.

Note: The useful energy estimates are based on air dry upper heating calorific values of 4500 kcal/kg (18.8 MJ/kg) for firewood, 3140 kcal/kg (13.1 MJ/kg) of dungcake, 3800 kcal/kg (15.9 MJ/kg) for Agricultural residues and 10,300 kcal/kg (43.1 MJ/kg) for kerosene (Source: Weighted average of common agricultural residues and woody biomass taken from Joshi *et al.* 1989 and TEDDY 1995). The efficiency of energy conversion is assumed uniformly at 10% for biofuels and 40% for kerosene wick stove.

Table 9. NCAER estimates of state-wise biofuel consumption (in air dry kg/cap/d)

State	Firewood	Dungcake	Agricultural residues
Arunachal Pradesh	0.31	0.00	0.20
Assam	0.31	0.00	0.20
Bihar	0.33	0.73	0.22
Goa	0.31	0.25	0.04
Gujarat	0.40	0.25	0.02
Haryana	0.14	0.70	0.21
Himachal Pradesh	1.31	0.02	0.00
Karnataka	0.60	0.02	0.14
Kerala	0.41	0.00	0.23
Madhya Pradesh	0.47	0.52	0.12
Maharashtra	0.31	0.25	0.04
Manipur	0.77	0.00	0.23
Meghalaya	0.77	0.00	0.23
Mizoram	0.77	0.00	0.23
Nagaland	0.77	0.00	0.23
Orissa	0.46	0.33	0.08
Punjab	0.25	0.58	0.32
Rajasthan	0.57	0.39	0.04
Sikkim	0.31	0.00	0.20
Tamil Nadu	0.47	0.11	0.11
Tripura	0.77	0.00	0.23
Uttar Pradesh	0.38	0.58	0.17
West Bengal	0.25	0.27	0.43
UNION TERRITORIES	0.25	0.36	0.17

Source: NCAER 1985

Table 10. Summary of biofuel consumption in agroclimatic regions (IREP estimates) (in air dry kg/cap/d)

Agroclimatic zone	Firewood	Agricultural residue	Dungcake
Western Himalayan zone	1.95	0.14	0.22
Eastern Himalayan zone	1.70	0.00	0.00
Middle Gangetic zone	0.75	0.65	0.50
Upper Gangetic zone	0.36	0.35	0.43
Trans Gangetic plains	0.37	0.96	0.65
Eastern plateau and hills	1.60	0.00	0.00
Western plateau and hills	0.79	0.38	0.47
Southern plateau and hills	0.62	0.30	0.19
East coast plains and hills	0.60	0.08	0.13
West coast plains and ghats	1.29	0.21	0.00
Gujarat plains and hills	0.92	0.30	0.22
Western dry regions	1.08	0.03	0.44

Source: Computed from Planning Commission, 1992.

Table 11. Biofuel use by State in the rural domestic sector (in air dry million tonnes/year)

State	Firewood			Dungcake			Agricultural residues		
	REDB	IREP	NCAER	REDB	IREP	NCAER	REDB	IREP	NCAER
Andhra Pradesh	23 2	10.8	9.74	9.5	2.9	2.26	18.6	3.6	1.75
Arunachal Pradesh	0 5	0 5	0.09	0.1	0.0	0 00	0.1	0.0	0.06
Assam	13.7	12.3	2.26	1.4	0.0	0.00	2.7	0.0	1.46
Bihar	34.1	26.9	8.90	8.2	9.9	19.89	7.8	13.0	5.99
Goa	0.0	0.0	0.08	0.0	0.0	0.06	0.0	0.0	0.01
Gujarat	8.6	9.1	3.99	2.3	2.2	2.47	3.0	3.0	0.23
Haryana	1.7	1.7	0.61	2.6	2.9	3.14	1.5	4.3	0.96
Himachal Pradesh	1.8	3.3	2.23	0.3	0.4	0.03	0.0	0.2	0.00
Karnataka	10.6	8.3	6.74	2.6	1.8	0.27	7.8	3.2	1.62
Kerala	7.4	10.0	3.19	1.2	0.0	0.00	1.0	1.6	1.78
Madhya Pradesh	32.6	13.1	8.68	6.2	1.8	9.62	5.7	1.5	2.32
Maharashtra	20.0	16.0	5.45	2.9	6.7	4.32	7.6	5.8	0.70
Manipur	0.9	0.8	0.37	0.1	0.0	0.00	0.2	0.0	0.11
Meghalaya	1.0	0.9	0.40	0.1	0.0	0.00	0.2	0.0	0.12
Mizoram	0 3	0.2	0.10	0.0	0.0	0.00	0.1	0.0	0.03
Nagaland	0.7	0.6	0.28	0.1	0.0	0.00	0.1	0.0	0.08
Orissa	26.0	11.2	4.56	4.3	0.6	3.33	7.6	0.4	0.76
Punjab	1.9	1.9	1.31	3.0	3.4	2.99	1.8	5.0	1.63
Rajasthan	9.8	4.3	7.05	7.8	2.1	4.76	2.8	0.8	0.51
Sikkim	0.3	0.2	0.04	0.0	0.0	0.00	0.1	0.0	0.03
Tamil Nadu	17.9	8.5	6 31	7.5	2.0	1.49	13.9	2.5	1.49
Tripura	1 6	1.4	0.66	0.2	0.0	0.00	0.3	0.0	0.20
Uttar Pradesh	16.6	21.9	15.56	37.2	17.2	23.50	5.6	17.3	6.98
West Bengal	20.3	4.4	4.52	9.0	0.0	4.85	10.5	0.0	7.74
Union Territories	0.4	0.4	0.16	0.4	0.3	0.22	0.3	0.4	0.10
All India	252.1	169.0	93.3	106.9	54.2	83.2	99.2	62.8	36.7

Sources: REDB - this study; NCAER: computed from NCAER 1985 (see also Table 12) and IREP: computed from Planning Commission, 1992.

Table 12. National aggregates of biofuel use in the rural domestic sector (in air dry million tonnes/year)

Source	Firewood	Dungcake	Agricultural residues
Consumption			
NCAER	93.3	83.2	36.7
REDB (low)	181.3	40.1	31.6
REDB (average)	252.1	106.9	99.2
REDB (high)	309.4	114.5	165.5
IREP	169.0	54.2	62.8
Requirements			
ESI (510 kcal/cap/d or 2.13 MJ/cap/d)	151.3	41.5	47.8
EDSG (520 kcal/cap/d or 2.18 MJ/cap/d)	201.7	55.3	63.7
ABE (620 kcal/cap/d of 2.60 MJ/cap/d)	240.5	65.9	76.0

Sources: NCAER aggregates based on NCAER 1985 (see Table 12); IREP estimates computed from Planning Commission 1992; REDB estimates are based on this study; and ESI, EDSG, and ABE are based on ESI (1965), EDSG (1985) and ABE (1985) respectively.

List of variables in the database

Label	Description
AGENCY	Agency Name
AGL_PC	Ag-land/Pop (ha./pc)
AGRO_C	Agro-Climatic Zone
AGRO_I	No.of agro-industry (Nos.)
AGR_COK	Agriculture residues for cooking (kg/p/d)
AGR_ENR	Energy use in agriculture provided (Y/N)
AG_LAND	Agricultural land (ha.)
AG_PRCE	Agricultural residues (Rs/kg)
ANIMT_E	Animate energy consumption (Y/N)
AREA_PC	T-area/Pop (ha./pc)
BLOCK	Block
CATLE	No.of main cattle (All Age) (Nos.)
CATLE_A	No.of main cattle, adult (Nos.)
CATLE_O	No. of other cattle (Nos.)
CON_ELE	Electricity consumption per unit (Kwh/d)
CON_HSD	Diesel consumption per unit (l/d)
CRP_YLD	Crop yields provided (Y/N)
C_FERTS	Use of chemical fertiliser (Y/N)
C_H_RATIO	Catle/Pop (Nos./pc)
DC_COK	Dungcake for cooking (kg/P/d)
DC_PRCE	Dungcakes (Rs/kg)
DISTR	District
DIST_MR	Distance from main road (Km.)
DIST_PHC	Distance from P.H.C. (Km.)
DS_PRCE	Diesel (Rs/l)
D_PUMP	No. of diesel pumpset (Nos.)
ELECTRI	Electrified (Y/N)
ELEC_HH	No.of electrified household (Nos.)
ELEC_HH%	Percentage of households electrified (percentage)
ELEC_LI	Electricity for lighting (kWh//hh/d)
E_PUMP	No.of electric pumpset (Nos.)
FW_PRCE	Firewood (Rs/kg)
F_WOD_C	Firewood for cooking (kg/P/d)
GOAT	No. of Goat/Sheep (Nos.)
HANDPMP	No.of handpumps for drinking water (Nos.)
HHNum	No.of household (Nos.)
IN_CAP	Capacity of prime-mover of agro industry (kW)
IRR_L%	Irrigated land as a percentage of agricultural land
KO_PRCE	Price of kerosene (Rs/l)
KOiL_CO	Kerosene for cooking (l/P/d)
KOiL_LI	Kerosene for lighting (l/hh/d)
LAN_CAT	Information on other land category provided (Y/N)
LAN_LES	No. of landless household (Nos.)
LAN_LES%	Landless households as a fraction of total

LAN_O	Categories of land owned provided (Y/N)
LAN_O%	Landowning households as a fraction of total
LAN_OWN	No.of land owners (Nos.)
OTH_PRC	Prices of other commodities provided (Y/N)
POP	Population (Nos.)
SCH_TY	Type of highest school (P/M/H)
SEAS_V	Seasonal variation provided (Y/N)
SPACE_H	Space heating (Y/N)
STATE	State
SUR_HH	No.of surveyed house holds (Nos.)
SUR_HH%	Surveyed households as a percentage of total
households	
THRSHER	No.of threshers (Nos.)
TOT_SCH	Total no.of school (Nos.)
TRACTOR	No.of tractors (Nos.)
T_AREA	Total area (ha.)
T_IRR_L	Total irrigated land (ha.)
VILL	Village
WATER_H	Water heating (Y/N)
WELLS	No.of wells for drinking water (Nos.)
YEAR	Year of Survey

Session VII

Survey Techniques — II

In this session various techniques of collecting information from primary sources have been discussed. The participants will be told about the various tools employed in primary surveys like questionnaires, participatory rural appraisal/ rapid rural appraisal (PRA/ RRA) techniques and the skill of administering them in the field.

Contents

- Questionnaire design
- Sampling
- Interviews
- PRA/RRA methods

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Questionnaire design: pretesting and field execution

Introduction

A successful questionnaire design concentrates on the relevant research issues in such a way as to encourage the respondent to provide accurate representations of his attitude and behaviours. Faulty questionnaire design is a major contributor to nonsampling errors which are a much larger part of the total survey error than are sampling errors. Most survey research data are collected by means of structured questionnaires but under certain circumstances unstructured questionnaires are also used.

As mentioned above, there are two types of questionnaires:

Structured questionnaire

The order in which questions are asked, together with their wording are predetermined. Most of the questions are closed and possible answers to most questions are precoded.

Unstructured questionnaire

Most of the questions are open ended. The interviewer is free to change the order of asking questions and to explain them. The questionnaire may take the form of a check-list for discussion. The unstructured questionnaire is used in for carrying out 'depth' interviews, and group discussions.

Design of a structured questionnaire

The stage in the development of a structured questionnaire are illustrated in the flow chart (figure 1).

EXPLORATORY RESEARCH
Formulation of hypotheses

Topics of Interest
Population of interest

Level of generality of topics
Classification of population ------► plan of tabulations

Ordering of topics

Treatment of topics
Direct/indirect questions
Open/closed questions
Pre-coding

Questionnaire layout
Design of supporting
material e.g.
Prompt/ 'show' cards
Self-rating scales

Pilot test design
To optimise:
- Ordering of questions
- Closing of open questions
- Instructions to interviewer
- Efficiency of layout

To confirm
Time taken by interviews
Cost of interviews

Figure 1. Stages in the development of a questionnaire

After formulation of hypotheses, we should know what topics are relevant to the decision making task and from what population the sample is to be drawn.

Level of generality of topics, classification of population and tabulation

To decide on the level of generality of the topics one has to decide:

1. In what detail we need to ask questions about survey topics.
2. How we are going to break down survey population? What groups are going to be critical?
3. The tabulation should be planned bearing in mind that too much detail is as counter - productive as too little detail. Tabulations must be decided upon before the questionnaire is finalised to ensure that all the data are available to draw

Treatment of topics (response formats)

Two types of response formats can be used in constructing the questionnaire:

Open-ended questions

In responding to such questions the respondent is free to answer within the limits implied by the question. The primary purpose of such formats is to obtain the respondents own verbalisation of, comprehension of, and reaction to stimuli. The stimuli may cover a broad range (such as products, demonstration etc.). However, open ended questions are useful under the following circumstances:

1. To check/corroborate the results of the quantitative or closed ended questions.
2. To obtain direct comparison and more specific areas of preference and rejection when two or more stimuli (ideas or concepts) are involved in a test.
3. To determine whether a particular communication vehicle (e.g. demonstration) conveys its intended objectives.
4. To determine respondent's affective reactions or feelings as a result of exposure to a stimulus (commercial, concept, package, product, or advertisement).

The drawbacks of open-ended questions are:

1. Answers to such questions may be a more direct result of the respondents ability to articulate than his knowledge or interest in the issue being investigated.
2. Interviewer's bias is a serious problem.
3. Coding and categorization of answers in tedious task.

To overcome these shortcomings precoding is used.

Close-ended (itemised) questions

With a close-ended question format, the respondent is provided with predetermined descriptions and is asked to select one that best describes his or her feelings.

The advantages of these question formats are:

1. Ease of use in the field.
2. Ability to reduce interviewer bias.
3. Simple in terms of coding and tabulation.

However, close ended questions require substantial effort during pre-testing stage to ensure that pre-determined set of response categories adequately reflect all possible and relevant responses.

The art of asking questions

Having determined the topics to be covered and in what detail individual topics should be investigated, the questions can be formulated. The issues to be considered are:

- Has the respondent got the information?
- Will the respondent understand the question?
- Is the respondent likely to give a true answer?

Has the respondent got the information?

It is easy to assure that the respondent has had the experience necessary to give a valid answer. It is a good practice to find out about how it is used or regarded.

Will the respondent understand the question

A number of specific considerations should be kept in mind when asking questions. The basic principles are:

1. Be clear and precise,
2. Response choices should not overlap,
3. Use natural and familiar language,
4. Avoid leading questions, and
5. State explicit alternatives.

Is the respondent likely to give a true answer?

Given that the respondent has the information and understands the question. what are the chances of the question eliciting a true answer? There are three outstanding hazards:

- The respondent may find it difficult to verbalise,
- The respondent's memory may be defective, and
- The respondent may be reluctant or unwilling to answer the question.

The validity and reliability of data can be severely compromised if respondents cannot accurately answer the questions asked.

Ordering of questions

The typical flow in research surveys should be - a progression from *evaluative* to *diagnostic* questioning or vice-versa and then on to *classification* questions. However, such a sequence is more valid in the case of *probability sample*. In case of a *non-probability sampling*, some classification questions need to be asked at the outset, because it is necessary to establish that the respondents fits into the sample size.

Checklist of major points to be considered when planning the flow of the questionnaire

1. Start with easy, nonthreatening, but necessary questions. Put the more difficult or threatening questions near the end of the questionnaire.
2. Since some demographic questions are threatening, i.e. the respondent might full UNCO inforsable while responding to such questions, put these questions at the end of the interview. If possible, avoid asking demographic questions first.
3. For personal interviews use funnelling procedures to minimise order effects. Start with the more general questions and move to more specific questions.
4. If questions deal with more than one topic, complete questions on a single topic before moving on to a new topic.
5. When switching topics, use a transitional phrase to make it easier for respondents to switch their train of thought.
6. To ensure that all contingencies are covered, make a flow chart for filter questions Filter questions should not require extensive page flipping by the interviewer or respondent or require remembering answers to earlier questions.
7. If multiple filter questions are to be asked, try to ask all of them before asking the more detailed questions.

Questionnaire layout

Number of precautions need to be taken in designing the physical format of the questionnaire. A checklist of major points is reproduced below:

Checklist of major points to consider in designing the lay out of the questionnaire

- Use booklet format for ease in reading and turning pages and to prevent loosing of pages.
- A self-administered questionnaire should look easy to answer and professionally designed and printed. A date, title of the study, and the name of the organization conducting the study should appear on the first page of the questionnaire.
- Do not crowd questions. Be sure that sufficient space is left for open-ended questions.
- Use sufficiently large and clear type so that there is no strain in reading.
- Each question should be numbered and subparts of a question should be lettered to prevent questions from being omitted in error and to facilitate the use of skip instructions. Indent subparts of questions.

- Do not split a question between two pages.
- Provide directions and probes for specific question at appropriate places in the questionnaire; identify these directions with distinctive type. such as capital or italics.
- Use vertical answer formats for individual questions.
- Place skip instructions immediately after the answer.
- Pre-code all closed-ended questions to facilitate data processing.
- Pre-Column the questionnaire.

Sampling

Sampling is a process by which the characteristics of a larger body called a population are inferred from a small number of elements called a sample.

Sampling Design Considerations

A sampling design usually involves five issues on which decision needs to be taken:

1. Target population and frame issues,
2. Data collection issues,
3. Sample-size determination issues,
4. Sampling techniques issues, and
5. Non-response-bias issues.

Target population and frame issues

The population of interest is called the target population while sampling frame is a list or set of directions (such as geographic breakdown) that identifies the target population.

Data collection issues

With respect to sampling design, the choice of a data collection method directly influences:

- the numbers of contacts required
- the type of sample to be drawn
- how sample size is determined
- the approach to handling non-responsed

Sampling size determination issues

Researchers use following methods to determine sample size:

Blind guesses

This is a completely arbitrary approach and usually not used.

Statistical precision

The use of statistical precision to determine sample size strictly applies to probability sampling designs only. A glossary of sampling terms in common use is enclosed.

Cost limitations

The cost limitation method of "all-you-can-afford" determines sample size on the budget allocated to the project. This approach is not very suitable since it emphasizes on cost reduction to the exclusion of all other factors, especially precision.

Nomograph

Nomograph which eliminates the need for calculation of sample sizes in estimation problems involving means. To use the nomograph it is necessary to specify the allowable error as a fraction of the assumed population mean to give the relative allowable error (RE). It is also necessary to estimate the variability as a ratio of the standard deviation *to the man* to give the coefficient of variation (CV). The sole purpose of using the assumed mean is to provide relative values so that single scales for RE and CV can be employed.

As was the case for the mean problem, a nomograph also exists for determination of sample size for proportions.

Standards

Industry standards refer to those rules of thumb developed from experience. that have become standard guidelines. No such guidelines are available in India and sample size widely varies with the type of research study.

Sampling technique issues

There are two broad categories of sampling methods: probability samples and non-probability samples. The categories can be further sub-divided as given under:

Non-response bias issue

The quality of data collected in a particular survey is a function of what can be called the total survey error. Total survey error reflects the difference between the overall population's true mean value (on the characteristics of interest) and the mean observed value (of the characteristic of interest) obtained from particular sample of respondents. Total survey error is composed of:

Total survey error = random sampling error + non-sampling error

Random sampling error occurs because the particular sample selected is an imperfect representation of the overall population. On the other hand, size of non-sampling error depends on two factors: non-response error and response error.

Non-response error occurs because not all of the respondent's included in the sample respond. Response error occurs when respondents give inaccurate answers. Non-sampling errors are more complex and harder to control than sampling errors and might constitute a much larger part of the total survey error if enough precautions are not taken.

Sampling methods

Cluster sampling

This is a method of random sampling in which the population is divided into groups, or clusters of elements, and then a random sample of these clusters is selected.

Random or probability sampling

This is a method of selecting a sample from a population in which all the items in the population have an equal chance of being chosen in the sample.

Stratified sampling

This is a method of random sampling in which the population is divided into homogenous groups, or strata and elements within each stratum are selected at random according to one of two rules: (1) A specified number of elements is drawn from each stratum corresponding to the proportion of that stratum in the population, or (2) an equal number of elements is drawn from each stratum, and the results are weighed according to the stratum's proportion of the total population.

Systematic sampling

This is a method of random sampling used in statistics in which elements to be sampled are selected from the population at a uniform interval that is measured in time, order, or space.

Comparative analysis of sampling methods

Sampling method	Cost	Ease of administration	Usefulness for generalizing to population
Non-probability			
1. Accidental	Quick and inexpensive	Very easy to execute	Results cannot be generalized to population
2. Quota	Quick and inexpensive	Only difficulties in ensuring that Quota is met	Objective is to represent certain segments, but generalizations to population are unreliable
3. Judgment	Quick and inexpensive	Easy to execute, but interviewer must determine what respondents are typical to the population	Results cannot be generalized to population, but method is useful in pretesting questionnaires
Probability			
4. Simple random	Somewhat more expensive and takes longer time	Requirement that population be listed makes it difficult to use the method for large populations	Useful for generalizing to population. Best when variation is not great among subgroups
5. Systematic	Slightly less expensive and takes less time than simple random	Can be easier to administer than simple random when population items need not be listed	Useful for generalizing to population. Should not be used when population items are grouped in a systematic fashion
6. Stratified random	Same as simple random	Easier than simple random if administrative convenience prescribes its use; harder if stratification is difficult	Can provide better representation of population than simple random if big differences exist between subgroups
7. Cluster	Less expensive and less time consuming than simple random for large populations grouped in clusters	More convenient to administer for large populations grouped in clusters	Can be generalized, but may be less representative than simple random
8. Area probability	Less expensive and time consuming than simple random for populations in large geographic areas	More convenient to administer because population need not be listed	Can be generalized to population

Glossary

Sampling terminologies

Population

A collection of all the elements we are studying and about which we are trying to draw conclusions.

Representative sample

A sample that contains the relevant characteristics of the population in the same proportion as they are included in that population.

Sample

It is a collection of some, but not all, of the elements of the population under study, used to describe the population. **Sample** a portion of the elements in a population chosen for direct examination or measurement.

Sampling distribution

Sampling distribution of a statistic for a given population, a probability distribution of all the possible values a statistic may take on for a given sample size.

Cluster

Within a population, groups that are essentially similar to each other, although the groups themselves have wide internal variation.

Interviews

Introduction

Interviewing is an important technique for collecting impression based as well as factual information. Traditional structured interviews have given way to more participatory and interactive forms of interviewing. Interviews could be (a) Informal conversational interviews (b) Interview guide approach (c) Standardized open ended interviews, and (d) Closed quantitative interviews. Participatory methods make use of the first two types of interviews which are semi structured interviews. For details on various types of interviews please see the annexure.

Semi-structured interviews

Semi-structured interviews (SSI) are more conversational, participatory yet controlled and structured. In such interviews, only some of the questions and topics are predetermined. The rest evolve during the course of the interview session. An interview guide is generally made use of to provide the interviewer with a checklist of possible questions that could be relevant to the topic. Semi-structured interviews are often carried out alongside other exploratory and participatory techniques, e.g. observation, ranking and mapping. They are not necessarily substitutes for the traditional structured interview, but rather complement it with in-depth information. The output are usually in the form of hypotheses and propositions. but can also be in quantitative form.

Types of Semi structured Interviews

Key informant interviews

These aim to obtain special knowledge. Key informants have special knowledge on a given topic. They are not necessarily the 'leaders'. A farmer who has experimented with different crops is as much a key informant as an extension officer; their information is complementary. Outsiders with inside knowledge are often valuable key informants who are able to answer questions about other peoples knowledge, attitudes and practices besides their own.

Group interviews

These provide access to a larger body of knowledge of general community information. An interview with more than 20 to 25 people is difficult to manage. The dynamics of

group interviews tend to pave the way for unexpected questions and provide additional information, i.e., 'the sum is more than an addition of individual replies'.

Focus group interview

These interviews addresses a specific topic. Focus groups are typically six to eight people who under the minimum guidance of a facilitator, discuss a particular topic in detail.

Individual interviews

Individual interviews are carried out with selected persons on the same topic such that a truly representative information reflecting different views and perceptions and thus a range of opinions, attitudes and strategies is obtained. Particularly, if the objective is to understand the perceptions of the people on a particular issue, it would be best to interview people from various social groups. For instance, men and women tend to have different experiences—hence opinions. Rich and poor people, people belonging to different ethnic or religious groups, and people of different ages represent different experiences. Similarly, different people have different past experiences. The bias of asking only one group must be avoided. To get a holistic overview of the issue as perceived by the entire community, individual interviews are useful.

The types of semi structured interviews have been discussed in detail in the annexure.

Guidelines & Check points: Semi Structured Interviews

SSI Guidelines

- The interviewing team should consist of 2 to 4 people from different disciplines.
- Begin with the traditional greeting and state that the interview team is here to learn.
- Begin the questioning by referring to someone or something visible.
- Conduct the interview informally and mix questions with discussion.
- Be open-minded and objective.
- Let each team member finish his/her line of questioning (don't interrupt).
- Carefully lead up to sensitive questions.
- Assign one note-taker (but rotate).
- Be aware of non-verbal signals.
- Avoid leading questions and value judgements.
- Avoid questions which can be answered with a 'yes' or 'no'.
- Individual interviews should be no longer than 45 minutes.

- Group interviews should be no longer than two hours.
- Each interviewer should have a list of topics and key questions written down in her notebook.

SSI Common Mistakes

- Failure to listen closely.
- Repeating questions.
- Helping the interviewee to give an answer.
- Asking vague questions.
- Failure to judge answers (believing everything).
- Asking leading questions.
- Allowing the interview to go on too long.
- Over-generalization of findings.
- Relying too much on what the well of, the better educated, the old, and the men have to say.
- Ignoring anything that does not fit into the ideas and preconceptions of the interviewer.
- Giving too much weight to answers that contain 'quantitative data'.
- Incomplete note-taking.

General Guideline for asking questions

1. Do not begin with difficult/sensitive questions. Put these near the end so that if the respondent decides not answer these, you do not lose his/her willingness to answer earlier questions.
2. Do not make respondents feel they ought to know the answers.
   Help them by saying, 'Perhaps you have not had time to give this matter much thought?' 'May be you can give the answer later'.
3. Respondents may not have the answer. Even though they would like to cooperate, respondents may not have the answer. Perhaps they do not know, cannot remember, cannot express the answer well in words, have no strong opinion, or are unfamiliar with answering questions.
4. Decide carefully whether you should avoid emotional or sensitive words.
   Using words like 'greedy', 'oppressed' or 'immoral' may seem to imply a judgement. Such words can cause bias in the answers. Respondents may be reluctant or nervous to give answers.
5. Avoid making assumptions. Do not ask questions like, 'How many cattle to you own?' Perhaps the respondent has no cattle.

6. Do not use confusing questions. Avoid asking questions like,'Would you prefer not to have a biogas plant?' Keep it simple and positive. Ask, 'Do you wish to have a biogas plant?'
7. There are Different ways of asking the same questions. These may be needed by the interviewer in order to be able to adapt the questions to different respondents.
8. Use both direct and indirect questioning. For example, asking a parent about an older child's health is not the same as asking the child about his/her own health. Older children can often provide important answers, but it is necessary to get their parent's or guardian's permission first before questioning them.

ANNEXURE

Type of interviews

Type of Interview	Characteristics	Strengths	Weaknesses
Informal conversational interview	Questions emerge from the immediate context and are asked in the natural course of things There is no predetermination of question topics or wording	Increases the relevance of questions Interviews are built on and emerge from observations The interview can be matched to individuals and circumstances	Less systematic and comprehensive if certain questions don't arise 'naturally' Data organization and analysis can be quite difficult Requires maximum attention by interviewer Difficult to leave interview to assistant
Interview guide approach	Topics and issues to be covered are specified in advance, in outline form Interviewer decides sequence and wording of questions in the course of the interview	The outline increases the comprehensiveness of the data and makes data collection somewhat systematic for each respondent Logical gaps in data can be anticipated and closed Interviews remain fairly conversational and situational	Important and salient topics may be inadvertently omitted Interviewer flexibility in sequencing and wording questions can result in substantially different perspectives, thus reducing the comparability of responses
Standardized open ended interviews	The exact wording and sequence of questions are determined in advance All interviewees are asked the same basic questions in the same order Questions are worded in a completely open ended format Several interviewers are used	Increases comparability of responses Reduces interviewer bias Facilitates organization and analysis of data	Standardizing the wording of questions may constraint and limit naturalness Little flexibility in relating the interview to particular individuals and circumstances
Closed quantitative interviews	Questions and response categories are determined in advance Responses are fixed	Data analysis is simple Saves time	Respondents must fit their experience and feelings into the researcher's categories

Semi-structured interviews: *Key informant interviews*

Purpose	Advantages	Limitations	Time perspective	Interviewer qualifications
Develop questions, hypotheses, propositions for further testing or in-depth/comprehensive study Generate descriptive information for planning and decision-making To understand rationale, motivations, attitudes that direct people's action/behavior Generate practical suggestions/ recommendations concerning some particular issue/ problem.	Can be carried out quickly Flexible: respond to individual differences, situational changes, emerging ideas/information Can provide in-depth information Inexpensive method of data gathering	Samples of informants is small: susceptible to bias caused by selection of informants Lack of acquaintance or confidence in interviewers may cause distortions in information Susceptible to 'interviewer bias': inaccurate/ distorted perception and interpretation or preconceived ideas/ conceptions on the part of the interviewer Do not (but in exceptional cases) generate quantitative data.	3 to 4 fairly extensive (about 20 questions) key informant interviews can be carried out by one interviewer in one day	The interviewer must possess knowledge of the subject or problem area and minimum practical experience of the subject/problem

Semi sturctured interviews: community interviews

Purpose	Advantages	Limitations	Time perspective	Interviewer Qualifications
Gathering descriptive data on a village/ community: access to facilities/ services, attendance/ use of services/ institutions Assessment of community needs/ problem/ priorities Assess beneficiaries' attitudes/ commitment/ willingness to assume responsibilities with respect to project activities Quantitative information regarding opinions/experiences/ behavior among community members Assess beneficiaries relevance to activities affecting whole community	Allow interaction with large groups of people in short periods of time Can be used to collect some quantitative/ descriptive community data In less hierarchical settings participants tend to correct/complement/verify each other thereby improving the validity of the data Observing/ recording group dynamics of meetings may produce insights in relations between local groups and categories of people It is a rapid and relatively cheap method for data collection	Communities are heterogeneous and this implies risks of elite domination/ manipulation in such interview settings Risks that local leaders and powerful/ prestigious community members monopolize the answering of questions Certain issues/ topics (family/personal matters, politically/ culturally sensitive/ controversial topics) should be avoided	A team of interviewers may carry out 3 to 5 community interviews in a week 1 to 2 weeks (depending on number of communities included) are required for literature review, selection of communities and preparation of an interview guide 2 to 3 weeks are needed for analysis and reporting	The interviewer/ moderator must possess good theoretical and practical knowledge situation/ topic to be explored. It is necessary to be fluent in the language in which sessions are conducted Interviewers should have previous experience in conducting community interviews

Semi-structured Interviews: Focus Group Interviews

Purpose	Advantages	Limitations	Time Perspective	Interviewer Qualifications
Generate information interpretation, understanding of perspectives, attitudes, behavior, problems of beneficiaries, field workers, project staff involved in planning, implementation or evaluation of development activities When ideas/ hypotheses on project components conceived at agency level need to be compared with grassroots-level ideas and opinions (improve, change or reject ideas, hypotheses, design) When behavior/ reactions of beneficiaries/ local groups need to be interpreted/ explained When reactions to project components/ innovations need to be interpreted/ established	Can be carried out quickly and obtain wide range of responses regarding a specific/ delimited issue or problem Economic: can be conducted by few persons during short field periods Homogeneous groups composition stimulates free expression and dynamic discussion Stimulate new perspectives ideas and complementary views/ opinions among participants	Moderator of focus group is interviews subject to risks of interviewer bias Formal/ informal leaders may monopolize discussions, influence and direct other participants' response patterns. If discussion enters sensitive/ intimate/ personal matters which are awkward, controversial or socially disapproved, the group situation may inhibit rather than stimulate individual responses Focus groups are not intended to reach consensus, make decisions or agree on specific action Do not generate quantitative data	1 to 2 weeks preparation: analyze situation or topic; for interview guide; select (categories of) interviewees 1 day is required for conducting a session and 1 day for writing summary of session 5 focus group sessions require at least 1 week for writing the report	The interviewer/ moderator must possess good theoretical knowledge of problem area/ situation/ topic to be explored. Moderator should be fluent in the language in which the session is conducted. Moderator should have previous experience in conducting focus group sessions.

Participatory rural appraisal (PRA)

Introduction

Rural development programmes have suffered from high costs, biased information, delays in decision making, emphasis on standard solutions and lack of participation from local people. A search has therefore been on for an approach which is less costly, facilitates timely collection of correct information, and encourages local solutions in a participative manner. The two approaches, namely, Rapid Rural Appraisal (RRA) and Participative Rural Appraisal (PRA) have been developed in succession as a result of this search.

Rapid rural appraisal (PRA)

RRA emerged in late 1970's. In 1988 RRA was described as a semi-structured way of relatively quick learning from the local people about the key problems and opportunities of an area and of deciding on an agreed set of possibilities for alleviating the problems and/or making good use of the opportunities. Its five key features are that it is (1) innovative, (2) iterative, (3) interactive, (4) informal, and (5) in-field.

RRA was an innovation as a method. It emphasized reversal of learning, i.e., it helped in reorientation of development planners and practitioners as learners rather than as just teachers and prescribers. However, the method was still elicitive-extractive in terms of collection of information. The information was owned and analysed by the outsiders for their own use in the form of plans, projects and publications.

From RRA to PRA

The word 'participation' and 'participatory' began to be used in connection with RRA in 1995. Participatory RRA was one of the seven types of PRA. In 1988, PRA conducted in Kenya resulted in a village resource management plan. This exercise was subsequently described as 'Participatory Rural Appraisal'. While an RRA exercise is intended for learning and analysis by outsiders, a PRA intends to enable local people to conduct their own analysis, and to plan and take action.

PRA is described as 'a family of approaches and methods to enable rural people to share, enhance, and analyze their knowledge of life and conditions, to plan and to act'.

Principles of RRA/PRA

Following are the principles that are shared by both RRA and PRA:

1. *Reversal of Learning* - Outsiders learn directly form people on the site, face to face, gaining from local physical, technical and social knowledge.

2. *Rapid and progressive learning* - Learning is rapid as it takes place with conscious exploration, flexible use of methods, improvisation, iteration and cross checking. The exercise at stages results in as many questions as answers. It thus improves the learning in a progressive manner.
3. *Offsetting Biases* - It make a deliberate attempt to avoid various biases particularly those of rural development tourism (spatial biases, project bias, person biases, dry season biases, diplomatic biases, professional biases) by being: relaxed and not rushing, listening and not lecturing, probing instead of passing on to the next topic, being unimposing instead of being important, and seeking out the poorer people and women to know about learn their concerns and priorities.
4. *Optimisation of Trade-offs* - It optimizes trade-offs between quantity, relevance, accuracy and timeliness of information by following the principles of optimal ignorance and appropriate imprecision. The principal of optimal ignorance suggests not to try to know what is not worth knowing. The principle of appropriate impression suggests not to measure more than what is needed.
5. *Triangulation* - Since this method of learning is compressed in time and learning, there is need to approach information from several intentionally different point of view, usually a minimum of three (triangulation), to improve accuracy.

   At least three major dimensions should be triangulated: (1) team composition, (2) units of observation, and (3) research methods. Triangulation of team composition is accomplished by forming a multi-disciplinary team. Units of observation are triangulated by collecting information on the same item from different categories of people. The same information is obtained through different methods, tools and techniques for the purpose of triangulation of research methods.
6. *Seeking Diversity* - This method makes a conscious attempt to explore contradictions and anomalies. It is different from triangulation.

   PRA puts additional emphasis on the attitude and behaviour of outsiders in their interaction with rural people. Three additional principles of PRA which are behavioural in nature are as follows:

   1. *Facilitating Participation* - Outsiders facilitate investigation, analysis, presentation and learning by rural people themselves. They 'hand over the stick' to rural people.
   2. *Self Critical Awareness and Responsibility* - Facilitators continuously examine their behaviour and try to do better. They embrace error and make it a learning opportunity rather than blaming others for the same.

3. *Sharing of Information and Ideas* - Information and ideas are shared. between rural people, between them and facilitators, and between facilitators from the same or different organisations.

Methods of PRA

There is a long list of methods that are being used under RRA and PRA. The list has been growing and innovations are being sought in the existing methods. Some of the methods are listed below.

- Tapping secondary sources - files, reports, maps,.....
- Do it yourself - rapport building, equalising
- Direct Observation
- Semi-structured interviews
- Key informants
- Group Interviews
- Mapping - village map, social map, resource map, opportunities and services map.......
- Transect walks - microenvironments
- Time lines - chronology of events
- Wealth ranking
- Chapati analysis - village management
- Seasonality analysis - rainfall, migration, crops, credit,......
- Preference ranking - trees, fodder, credit source,.....
- Livelihood analysis
- Historical transect

Brief descriptions of the these methods are given below. The descriptions are by no means exhaustive. Many other ways to do the same exercises may exist or may be thought of.

Study of information from secondary sources

First of all, an attempt should be made to obtain and study whatever secondary information on socio-economic status, population, rainfall, topography, soil types, etc. is available about the area under consideration. However, this information should be considered only as suggestive and not as the ultimate truth. Such study will help to understand the area and may also provide some possible lines of enquiry.

Do it yourself

Outsiders ask the villagers to teach them perform some village tasks like ploughing, transplanting, weeding, collecting wood, thatching, etc. Such attempt makes the outsiders realise how difficult it is to carry these simple looking tasks. This works as an equalizer and helps to promote rapport between the villagers and outsiders.

Direct observation

Direct observation helps in collection of information, in suggesting additional topics for interviews and in cross checking of the collected information. It direct observation of key indicators like soil colour to indicate fertility, birth weight to indicate status of health and nutrition, housing to indicate poverty of prosperity, etc. often provide more valid information in a cost effective manner.

Semi-structured interviewing

Semi-Structured interviewing is a principal method of RRA/PRA. It is not only used directly to obtain information on certain aspects but is also used as a medium for many other PRA exercises. These have been discussed earlier.

Village map

Purpose

- To understand the location of the village in relative to nearby places and resources, access to the village, mode of transport, etc.

Steps

- Select a group of villagers
- Explore what is there in the east, west, north and south of the village.
- Explore access routes to the village.
- At an opportune moment, hand over a chalk/pen to the person in lead to relate the things on the ground/chart. Depending on the situation, different persons may take lead from time to time.
- If the whole exercise is to be done on the ground, the group should be motivated to transfer it to a chart.

Precaution

- Unnecessary time consuming details and undue emphasis on perfection and drawing aspects should be avoided.

Social map

Purpose

- To know the location of individual households belonging to different caste and economic groups in the village in order to understand inter-group social relations.
- To do census for population, literacy, health, etc. for households.

Steps

- Depending on the situation, either the same group who sketched the village map or a different group of villagers can be used for drawing the social map.
- The point where the group is sitting in the village may be made the reference point for exploring information about the nearby households. The exploration then can go on with various lead questions till all the households are covered.
- Let the participants locate different households on chart/ground during the above discussion.
- Individual households on the map may be given an identification number. The names of the household heads with these numbers may be noted separately.

Figure 1 shows the social map of Jwalapuram village. In the map, the number mentioned in the households indicate the caste groups to which the respective households belong.

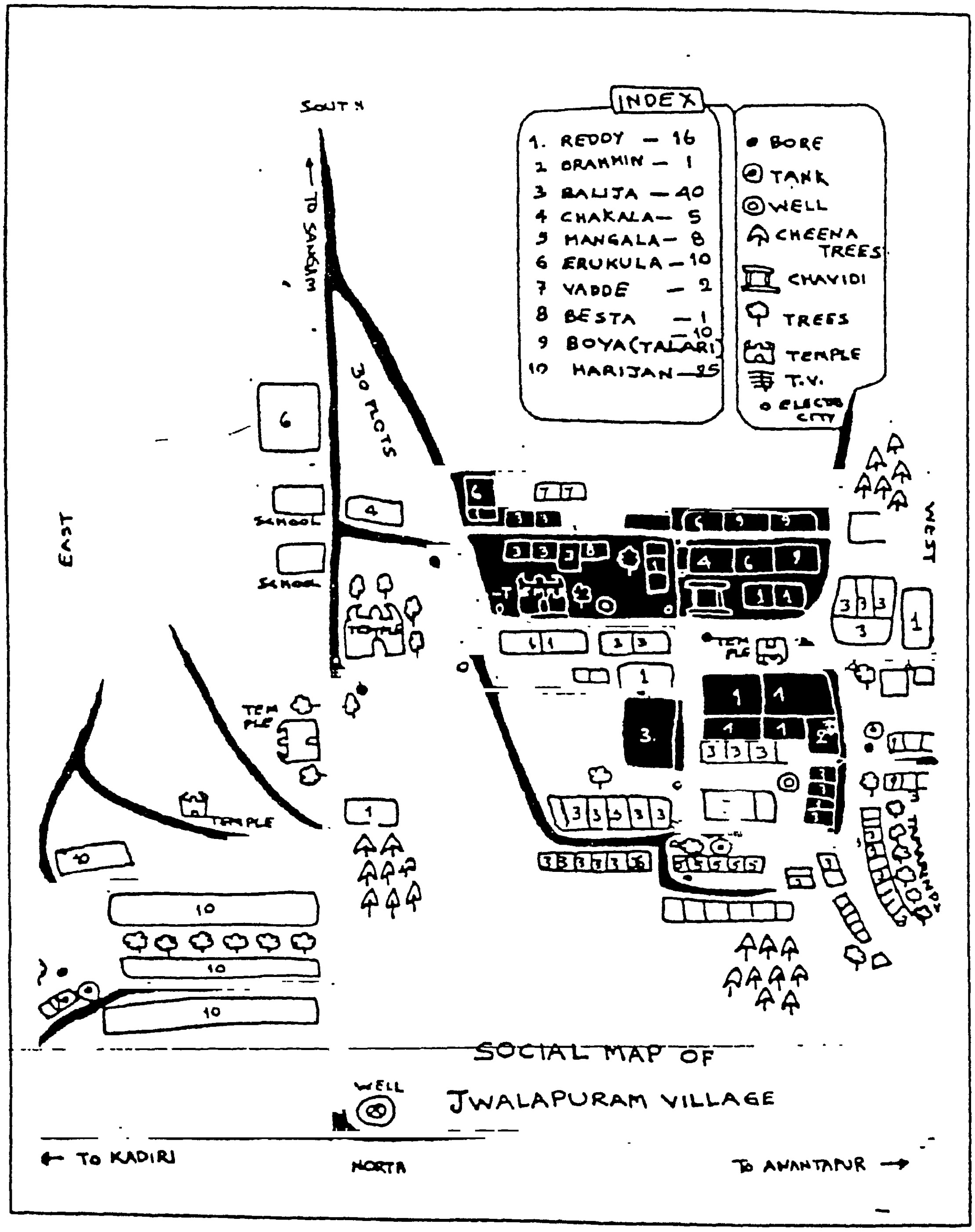


Figure 1. Social map of a village

Resource map

Purpose

- To understand the quality. quantity and location of natural resources like land. water. forest, etc. in the village.

Steps

- Let the villagers draw a sketch map of the village with only important landmarks within the village. If planned properly, the village map drawn earlier can also be used for this purpose.
- Discuss with the villagers about the topography, qualities of land, tree cover, sources of irrigation, etc. in different parts of the village.
- Facilitate the villagers to indicate all these on the map.
- Figures 2 gives a resource map for reference.

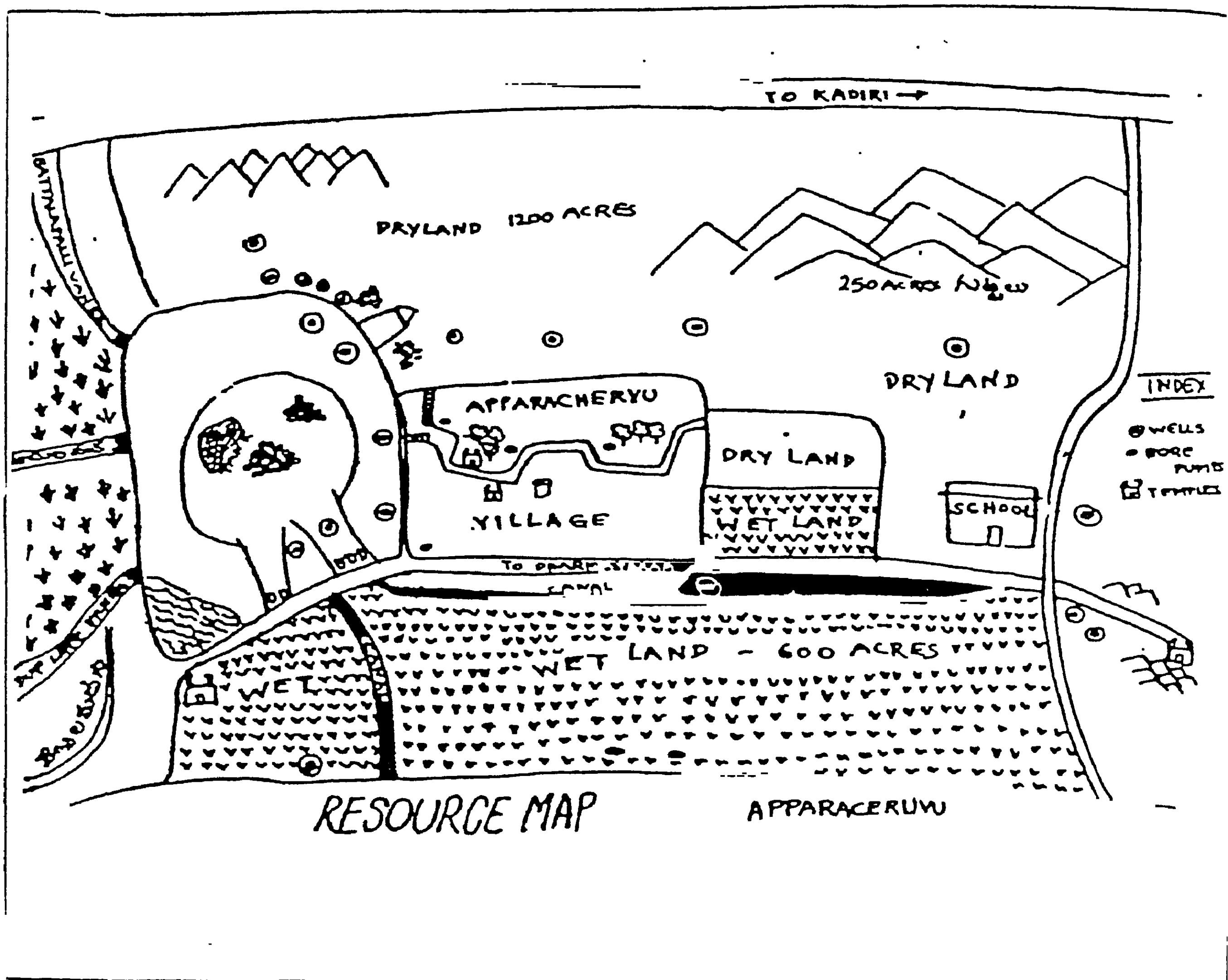


Figure 2. Resource map

Services and opportunities map

Purpose

- To understand the availability of various services and opportunities related to education, employment, health, marketing, etc.

Steps

- Discuss each possible service or opportunity and locate their availability on a village map.

Wealth ranking

Purpose

- To classify households into relative economic categories like rich and poor; rich, middle and poor, etc.

Use

- Choosing beneficiaries of a programme
- Doing some PRA exercises with different economic groups
- Studying livelihood strategies of the poorest.

Steps

- Have small cards on which names of household heads, identification numbers, assets, etc. could be written. Cards of approximately 3" x 2" size may be quite suitable for the purpose.
- Note the names of the household heads on separate cards when identifying different households at the time of social mapping.
- Give an identification or serial number to each household and put these numbers on both the social map and the cards.
- These cards can be used for wealth ranking at an appropriate stage. If the wealth ranking is to be done simultaneously with two or more informants then as many sets of these cards have to be prepared.
- Select minimum two key informants from amongst the villagers to provide information on wealth ranking.
- Do the wealth ranking exercise separately with each key informant in isolation.
- Decide the number of categories with the informant into which the households are to be divided. Two to five categories may be all right. Alternatively, the number of

categories may not be determined in the beginning. Let the exercise start and let the key informant go on placing the cards one by one in a relative manner. The number of categories will automatically emerge.

- Take one card at a time from the stack, read the name of the household and ask informant to place the card on ground near the marked category to which the household belongs. Marking of categories in a vertical manner from the rich at the top to the poor at the bottom may be more convenient.
- Once all the cards are placed, ask the informant the basis he has used to classify the households.
- Ask the informant to take another look at the households in each categories keeping in mind the above basis. He may change categories of some households in this round.
- Depending on the need, the items of the basis may be noted on each card, preferably in symbols. It will be difficult to do so if the same cards are to be repeated with other informants.
- Number the category of each household, like 1 for the rich, 2 for the middle and 3 for the poor. These may be written on each card. If so, this number should be distinct from the identification number put on the cards earlier.
- The category number/ rank for each household may be extended on a scale of 100 (know as category score) in the following manner:
  (a) (Category number of the household x 100) / (no. of categories)
  (b) If there are three categories as mentioned above then each household in the categories of rich, middle and poor will have a category score of 33.3, 67.7 and 100, respectively.
- Once the classification has been done with all the informants, the ranks given by different informants to each household may be aggregated. Use of category scores rather than the category number may be more convenient for this purpose. For this, prepare a list of all the households and mention all the category scores given by different informants to each households. Take average of all the category scores given to a single household. The order of the households may be re-arranged in a descending order, that is, from the poorest to the richest.

Figure 3 shows a part of the results of a wealth ranking exercise in Markathur village. It is clear that while the group IV and V have done ranking on the basis of four categories, the group III has done it on three categories. The number of categories is not clear in case of the groups I and II. These groups have probably used more than one informant and have averaged the scoring. The ranking of household number three creates doubt as it belongs to almost all categories scoring from 33 to 100.

S NO.	NAME (Head of House hold)	I	II	III	IV	V	Average
	← Results of 5 groups →						
1.	பழனியப்பன் (அகமுடையான்)	83	66	100	100	100	90
2.	பழனிமுத்து (வேளாளர்)	33	33	33	50	25	35
3	சிலம்பகம் (அகமுடையான்)	66	33	66	100	75	68
4	கருப்பையா (ஆசாரி)	26	11	33	25	25	24
5.	ராமநாதன் கோயில் ✡	—	—	—	—	—	—
6.	R.P சங்கர் (யாதவர்)	50	66	100	100	100	83
7.	அழகிய வர்தம் (யாதவர்)	66	66	100	100	100	86
8.	P. முத்துராக்கு (யாதவர்)	66	66	100	100	75	81
9	P சங்கர் (யாதவர்)	83	66	100	100	100	90
10.	உடையார் (வேளாளர்)	83	55	66	75	75	78
11.	கருப்பையா (வேளாளர்)	33	22	66	50	25	39
12.	முருகன் கோயில் ✡	—	—	—	—	—	—
13	சுப்பிரமணியன் (வெள்ளாளர்)	100	66	100	75	100	88
14	[illegible]	—	—	—	—	—	—
15	மாணிக்கம் (வெள்ளாளர்)	33	66	66	50	25	48
16.	நாளிமுத்து (வண்ணான்)	100	[illegible]	100	75	100	83
17	கோபால் (வண்ணான்)	33	22	66	25	25	34
18	சேவுகன் (வண்ணான்)	33	22	66	25	25	34
19.	மாணிக்கம் (யாதவர்)	33	55	66	50	75	56
20	பர்பூரணம் (வெள்ளாளர்)	26	22	M	50	25	—
21.	ஜோசப் (யாதவர்)	83	77	100	100	100	92
22.	கண்ணப்பன் (யாதவர்)	100	77	100	100	100	95
23	நாகூச்சாமி (வெள்ளாளர்)	66	88	66	100	100	84
24.	பாலசுப்பிரமணியன் (வெள்ளாளர்)	50	88	66	50	50	62
25.	K M சுப்பிரமணியன் (யாதவர்)	83	77	100	100	100	92
26	K சங்கர் (யாதவர்)	66	55	100	100	100	84
27	பிள்ளையார் கோயில் ✡	—	—	—	—	—	—
28	M.P. தங்கள் (யாதவர்)	83	55	100	100	100	88
29.	சங்கம்மாள் (யாதவர்)	50	33	100	75	75	67
30.	ராமச்சாமி (யாதவர்)	83	100	100	100	100	97
31	அழகு (யாதவர்)	83	55	100	100	100	58
32.	ஏ. மலைச்சாமி (யாதவர்)	66	55	66	75	75	67
33	ஏ. தங்கையா (யாதவர்)	83	66	66	100	100	82
34	[illegible] (வெள்ளாளர்)	50	33	66	50	25	45

Figure 3. Example of Wealth ranking exercise

Chapati analysis (Venn diagrams)

Purpose

- To identify key persons, groups and institutions that influence major decisions in the village. It helps to understand the management of the village.

Steps

- This exercise can be done either on paper by drawing circles of various sizes or by using circular pieces (like *Chapatis*) of paper.

Ask questions like

- Which is the most influential group in the village and who controls it?
- Which is the most influential group in the village and what are the interactions among various groups?
- Who resolves conflicts in the village?

Facilitate the participants to represent power of these groups by the size of the circles on a chart, or by cutting and placing round pieces of paper on the ground. Each circle or piece of paper should bear the name of the concerned person or group. The interactions can be shown by overlapping of circles. The distance of a circle from the main circle shows how peripheral or central a particular group is. Circles within a circle indicate the sub-groups.

Figure 4 shows a *chapati* diagram of decision makers.

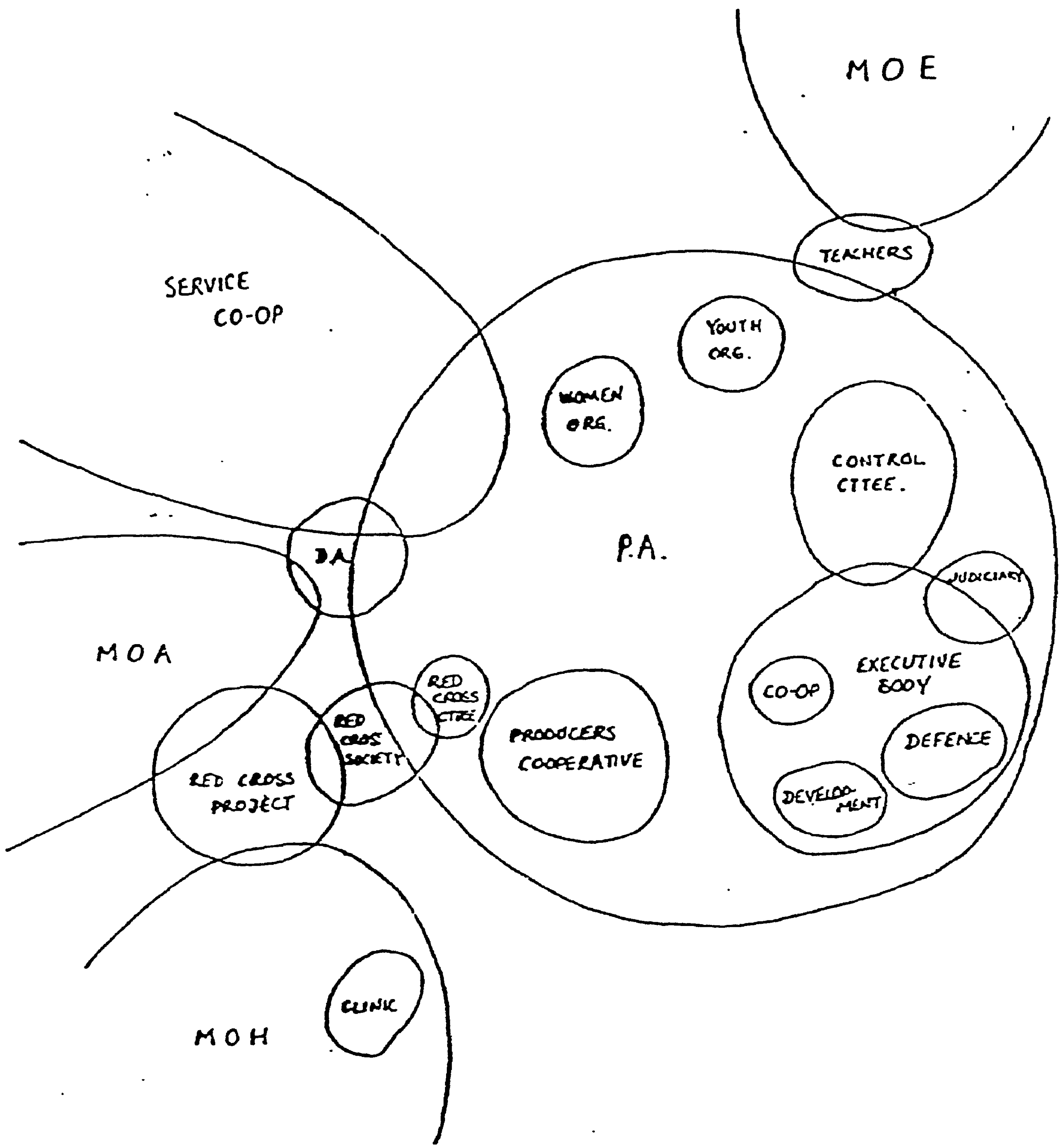


Figure 4. *Chappati* analysis

Time line

Purpose

- To understand changes in resources, resource-use pattern, group dynamics, technology adoption, etc. over time so as to explore possibilities and put things in proper perspective.

Steps

- Contact some elderly people in the village and let them speak about the village over time. The younger persons can also contribute for whichever point they can. The period over time can be identified in terms of years, events, etc. whatever is convenient.
- The happenings and changes against consecutive periods can be indicated in a vertical manner on a chart or on the ground.

Figure 5 shows time line for Udayanampatti village of Tamil Nadu. These are a mix of events that have taken place in the village over the years. Time line can also be done about the status of a particular item over the years. There is enough scope for doing the same exercise in different forms.

Resource	Persons.
Mr Krishnan	Mr Narayana Govindan
Mr Varnam	Mr Saldhana
Mr Thangamuthu	Mr Kottaisamy
Mr Manuharan	Ms Angammal
Mr Sonaimuthu	Ms Valli
Mr Suliyanayagam	

Year	Events
1902	Tank under taken by Govt
1935 to 1946	Establishment of Varanda School by Govt.
1947	Independence
1948	16 were died due to cholera, famine
1954	Road, Thatched school
1956 to 1964	Cyclone, flood's
1966	New school building
1968	Again cholera, A were died
1970	Electricity facility, bridge, 100 families migrated because of severe drought
1977	Establishment of Noon-meal center
1978	Community Well, 2 bore well for drinking purpose
1983	TINP
1984	Election boycott. One more bore well
1984 to 1985	Non Formal Education by Govt.
1987	SPEECH
1989	Group houses for 20 Harijans

Figure 5. Time Line of events

Village transect

Purpose

- To avoid biases verify maps, and understand various micro-environments existing in the village in the form of combinations of topology, soils, crops, animals, people, opportunities, etc.

Steps

- Take some villagers with you and start walking from one end of the village towards another end of the village. You can take a zig-zag route, S-shape route or any other route to cover as much area of the village as possible.
- Observe the micro-environments, discuss with the villagers, and facilitate them to indicate these micro-environments on a chart as you move along.

Figure 6 shows the village transect of Kambalia. It describes the status of topography, soil type, vegetation, livestock, land ownership, water sources, and problems faced in different segments of the transect.

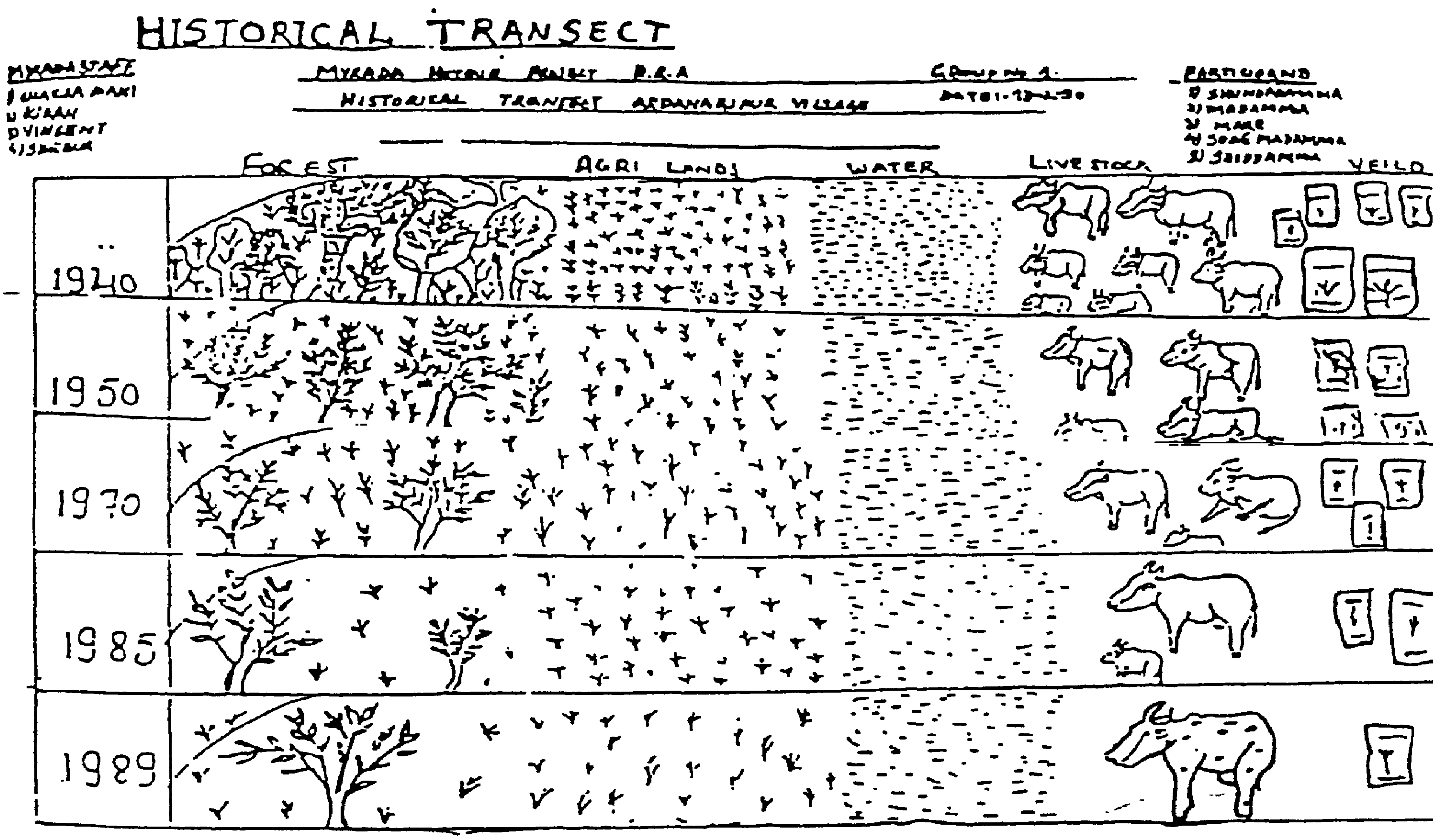


Figure 6. Village Transect (historical)

Seasonality

Purpose

- To understand periodic variations, usually within a year, in important activities, needs, climate, etc. Some of these are rainfall pattern, cropping pattern, fuelwood & fodder requirements, migration, employment, income, expenditure and credit needs.

Steps

- Identify the key persons, group or groups with whom this exercise has to be done. There are some items like rainfall pattern about which the response may not vary form person to person or group to group. However, there are items like employment, income and migration about which the response may change from one economic/caste group to another. The choice about the informants is to be made accordingly.
- Try to identify different periods in a year on a mutual basis. This may be on the basis of local names of the months, festivals, fairs, climate and so on. Visuals may be used to represent these periods to enhance accuracy and participation.
- Let the group mark these periods on a horizontal line either on the ground or on the top of a chart. It may be more convenient to start with the period that is close to the time of the exercise.
- Take up the items that are to be studied one by one and discuss with the group about its status from period to period. The items may be indicated one after another in a column just before the point where the first period starts.
- Let the group indicate the variations by using curves. branches of different lengths, different heap sizes of grains, seeds, etc, whatever medium is convenient. If it is done on charts, one may also use gum, adhesive taps, etc. to fix the material used. If the exercise has been done on the ground, it may be copied on to the chart for further use.

Figure 7 presents a seasonal calendar of agriculture and Limbi forest use patterns in the form of a circle. Another way of representing a seasonal calendar in a different form is by usung of bar diagrams and curves. The name of the months in this case are mentioned at the top.

SEASONAL CALENDAR

OF AGRICULTURE AND LIMBI FOREST USE PATTERNS, SOUTH GUJARAT

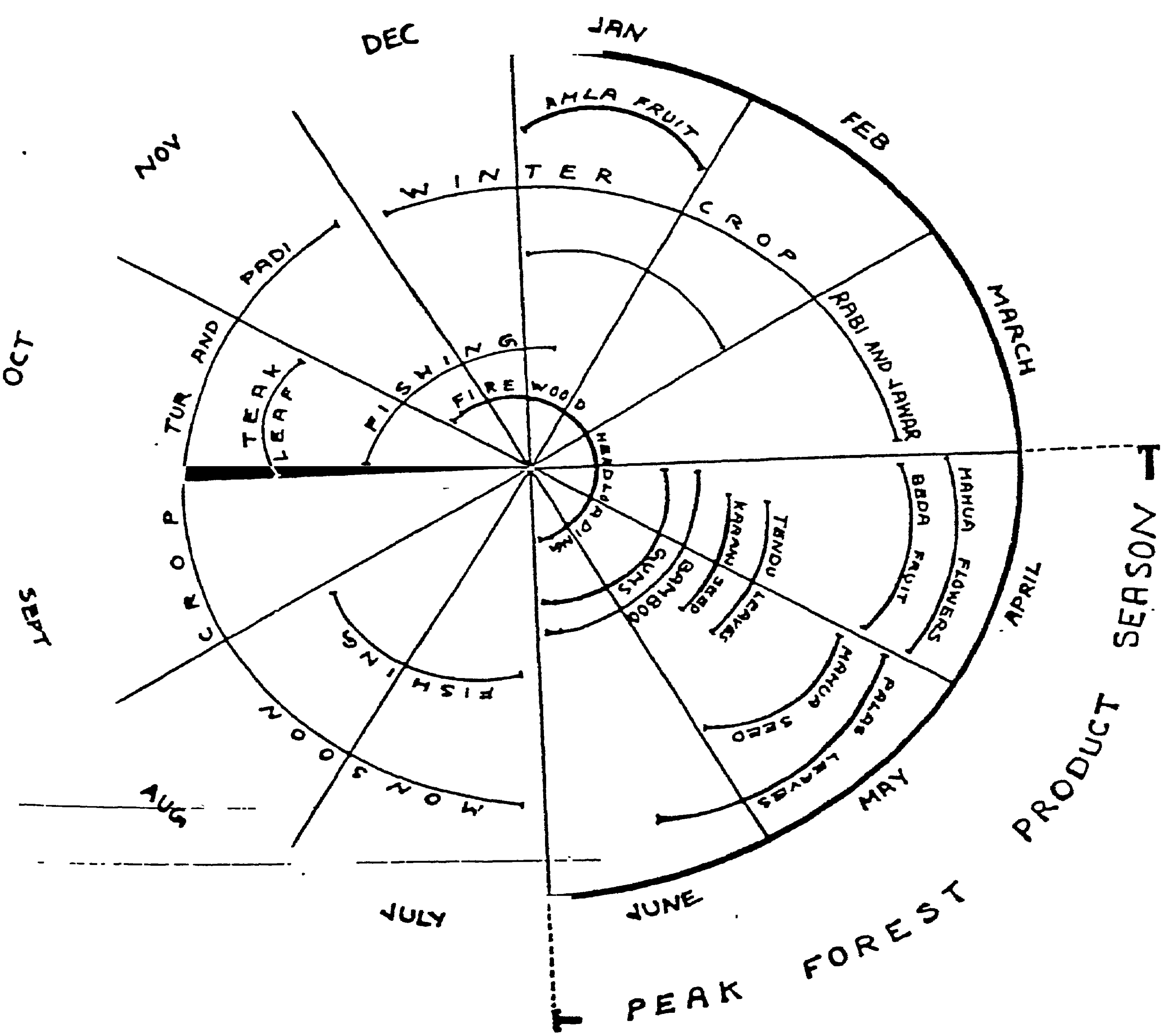


Figure 7. Seasonality calender

Preference ranking

Purpose

- To understand the preferences of people across various choices, e.g. choices for plantation, choice for credit, etc.

Steps

- Find out one or more key informants. These informants may be chosen from specific economic, caste categories depending on the purpose and type of ranking.
- Ask the informants to list all the choices available. For example, one can ask about the tree species grown in the area.
- The choices should be listed in the same order: both vertically in the left most column and horizontally in the top row, so as to form a matrix.
- Start from the first tree listed in the column and compare it one by one with all the trees listed in the row starting from the second tree. When comparing, ask which of the tree is better and why? Make a list of all the characteristics. In the present case, it may be the fuelwood quality, availability, sturdiness of the tree to survive against harsh conditions, etc.
- If, in the very first comparison, the first tree is preferred over the second tree, a tick can be placed in the second box of the first row. A cross can be put in the same box in the opposite case, that is, if the second tree is preferred over the first tree.
- Second time, the comparison of the second tree in the column will be made against the trees in the row starting from the third tree in the row. The first and second trees have already been compared and there is no point in comparing the second tree with the second tree. As you finish the comparisons, you will find that the diagonal from top left to bottom right and the portion below it have remained unused.
- List all the characteristics generated above in a column at the left and the same row of trees at the top.
- Start with the first characteristic and ask which tree in the row is the best according to this characteristic.
- The ranking of the trees against the same characteristic can be done in two ways: (a) by allocating an available score among different trees, and (b) by using the total number of listed trees as the maximum score and one as the minimum score. It may not be necessary to rank all the trees against each characteristic. Only the best three or so may be ranked.
- Lastly, the informants may be asked about one, two or three best trees taking all the characteristics in the account together.

Precaution

- Make the context clear when asking about the preferences. For example, the choice of the best tree may vary depending upon whether we are talking of private land, grazing land or forest land.

Figure 8 gives an example of a preference ranking exercise for trees. The figure compares different trees to determine the characteristics on which such preferences are based.

TREES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
NEEM	-	-	1	1	1	6	1	1.	1	1	1	1	1/13	14	15
PIPAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BABUL	-	-	-	4	5	6	3	8	3	3	3	3	3	14	15
NILGIRI	-	-	-	-	5	6	7	8	4	10	11	4	13	14	15
ARDUSO	-	-	-	-	-	6	7	8	5	5	1	5	13	14	15
MANGO	-	-	-	-	-	-	6	6	6	6	6	6	6	14	15
JUNGLE JALEBI	-	-	-	-	-	-	-	8	7	7	11	4	13	14	15
IMLI	-	-	-	-	-	-	-	-	8	8	11	8	13	14	15
VILAYATI BAVĀL	-	-	-	-	-	-	-	-	-	10	11	12	18	14	15
BER	-	-	-	-	-	-	-	-	-	-	11	10	13	14	15
KANAJ	-	-	-	-	-	-	-	-	-	-	-	11	13	14	15
DRUMSTICK	-	-	-	-	-	-	-	-	-	-	-	-	13	14	15
SISOO	-	-	-	-	-	-	-	-	-	-	-	-	-	14	15
BAMBOO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15
MALWA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

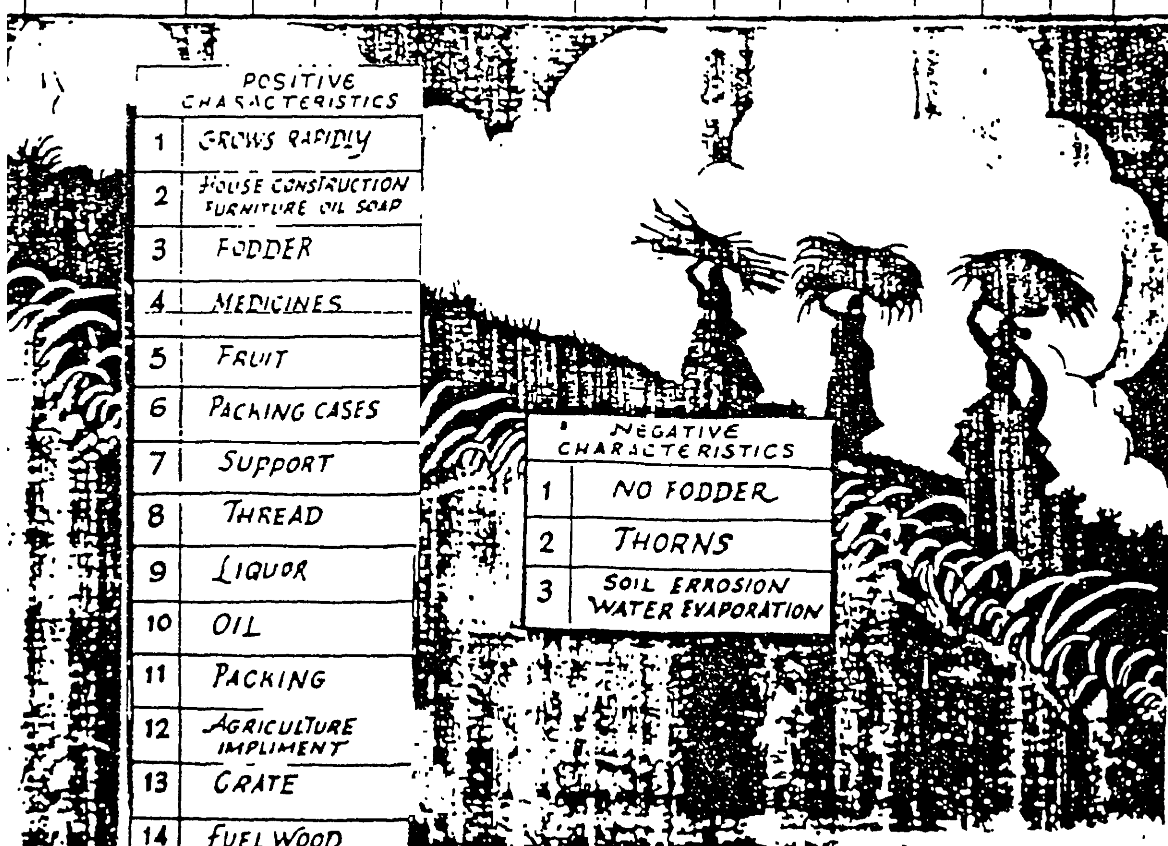


Figure 8. Preference ranking

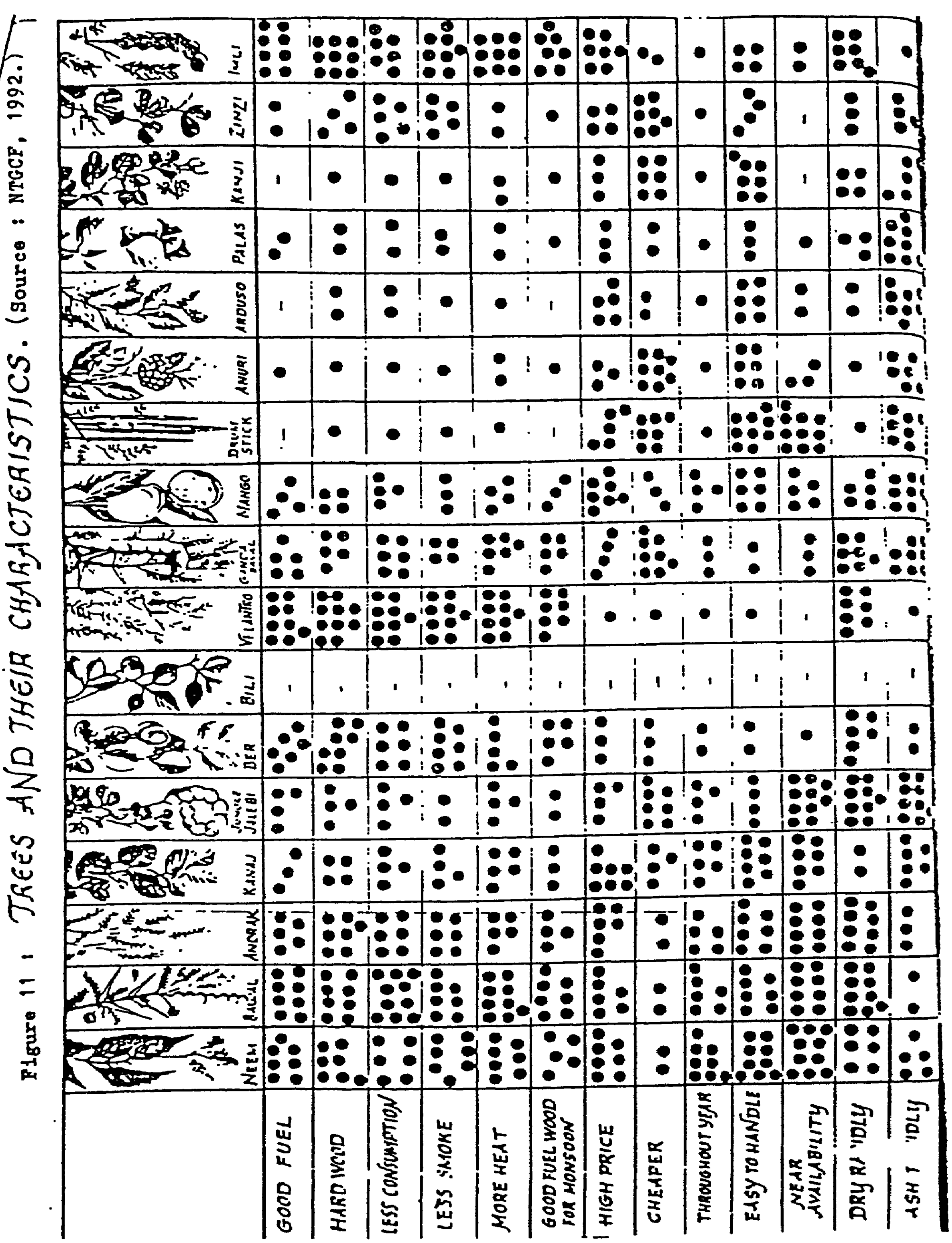


Figure 9. Preference ranking

Livelihood analysis

Purpose

- To understand how people live and make ends meet.

Steps

- Select individual families for doing their livelihood analysis.
- Interact with each family separately on a variety of issues and subjects to get a comprehensive picture of each family's lifestyle and factors affecting it.
- The information may be captured in the form of time line, pie diagrams, seasonality, etc.

Modelling

Purpose

Modelling, presenting a three dimensional image, serves the same purpose as mapping in a much more effective manner. Its utility increases significantly if a future plan is being demonstrated through a model, e.g, planning of a tree plantation and check dams.

Steps

- Choose a comfortable place to prepare the model.
- Facilitate the use of the material available like soil, branches etc. to prepare the model.
- Have a discussion on the issues involved.
- Invite as many people as possible near the model to make a presentation, get feedback, and incorporate suggestions.
- Facilitate copying of the model on a chart for future use.

Materials needed

Charts, small cards, colour sketch pens, colour chalks, pencils, erasers, sharpeners, shallow tape, gum, notebook,......

General quidelines

Entry into the village

Entry into a village for doing PRA may not be difficult if the rapport with the people has already been established through earlier work or contact. If it is a completely new village, the organisations or persons having good credibility in the village may be contacted first

either directly or through some mutual contact. These organisations or persons can introduce the PRA team in a village meeting and state the purpose of visit.

The purpose of the visit should be stated clearly. No undue expectations should be generated.

Duration of exercise

This depends on the purpose of the exercise and availability of the villagers. Usually, such exercises take two to five days. However, the follow-up of these exercises will take much longer. These should be done on a continuous basis.

Presentation to the village

A synthesis or understanding based on PRA exercises should be presented in larger village meeting for corrections. The presentations may be made by the villagers themselves who have played a key role in the respective exercises. The exercise should not end before discussing the future plan of action. Such meetings may be held each evening or whenever it is convenient for the villagers.

Danger

The core of a good PRA is our own behaviour and attitudes. It involves: (i) being self aware and self critical, (2) handing over the stick, (3) sitting, listening and learning, (4) improvising, inventing and adapting, and (5) using our own judgement at all times.

Session VIII

Data analysis and interpretation

In an energy planning exercise. the collection and compilation of data is followed by its analysis and interpretation. In this session various techniques of data compilation and analysis have been discussed. In a classroom exercise, inputs from participants would be taken to develop an energy plan.

Contents

- Data compilation, coding & entry
- Preparation of master sheet
- Data analysis
- Interpretation
- Actual plan development
- Key elements of a research project

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Data Analysis

Data compilation. Once the data has been collected from the field, the first step is to compile the data in a standardised form. These forms are called *master sheets.* These master sheets which facilitate the storage of data and also its proper retrieval, as and when required. Data entry in the master sheet is done by coding the variables and the data collected from the primary survey.

Coding. Coding of the data is done to facilitate the ease in developing the mastersheet and understanding the information collected. It is also done to ease data analysis. Generally, the variables collected are coded in Alpha-numeric pattern. All the data collected is coded in numeric pattern(Yes/No information is coded as 1/0 and if the data is not available then either the box is left blank or it is entered as -1). It is very important to maintain the uniformity in the data coded because while doing the analysis it becomes very essential to have a uniformity in the data values.

Mastersheet. Mastersheet is the basic document of all the surveys, as it is the place where the data is entered. Mastersheet contains all the information collected from the survey. Data entering in the master sheet is done after the variable and data has been coded. After prepration of the mastersheet, sub-sheets are prepared which are then used for individual analysis.

Data analysis. Data analysis can be done either manually or with the help of the spreadsheets (Computer based analysis). The analysis of data depends upon the hypothesis developed. Depending upon the nature of the analysis to be done, various statistical tools are used for analysis. Typically, data analysis involves calculating the average, standard deviation and variation in the data from the standard values.

Data interpretation. In important step in any planning study is data interpretation. The development of the plan or recommendations are made on the basis of these interpretations. Data interpretation is more qualitative in nature but is based on the quantitative output, which also substantiates the recommendations.

Data analysis terminologies

Data. A collection of any number of related observations on one or more variables.

Data Point a single observation from a data set.

Mean a central tendency measure representing the arithmetic average of a set of observations.

Median the middle point of a data set, a measure of location that divides the data set into halves.

Mode the value most often repeated in the data set. It is represented by the highest point in the distribution curve of a data set.

Standard deviation. The positive square root of the variance; a measure of dispersion in the same units as the original data, rather than in the squared units of the variance.

$$\sigma^2 = \frac{\sum (x-\mu)^2}{N} = \frac{\sum x^2}{N} - \mu^2$$

This formula enables to calculate the **population variance**, a measure of the average squared distance between the mean and each item in the population. The middle expression, $\frac{\sum (x-\mu)^2}{N}$, is the definition of σ^2. The last expression, $\frac{\sum x^2}{N} - \mu^2$, is mathematically equivalent to the definition but is often much more convenient to use, since it frees us from calculating the deviations from the mean.

$$\sigma = \sqrt{\sigma^2} = \sqrt{\frac{\sum (x-\mu)^2}{N}} = \sqrt{\frac{\sum x^2}{N} - \mu^2}$$

The **population standard deviation** is the square root of the population variance. It is a more useful parameter than the variance, because it is expressed in the same units as the

data (whereas the units of the variance are the squares of the units of the data). The standard deviation is always the positive square root of the variance.

$$\mu = \frac{\sum x}{N}$$

The population **arithmetic mean** is equal to the sum of the value of all the elements in the population ($\sum x$) divided by the number of elements in the population (N).

$$\bar{x} = \frac{\sum x}{N}$$

To derive the **sample arithmetic mean**, sum the values of all the elements in the sample ($\sum x$) and divide by the number of elements in the sample (n)

$$\bar{x}_w = \frac{\sum (x \times w)}{\sum w}$$

The **weighted mean**, is an average that takes into account how important each value is to the overall total. We can calculate this average by multiplying the weight, or proportion, of each element (w) by that element (x), summing the results ( ), and dividing this amount by the sum of all the weights

Key elements of a research project

Introduction

Successful projects don't just happen. Success comes through careful planning backed by objective oriented research. The decision maker must exercise good judgement in deciding what information to collect to minimise risk to error in his decisions. Poor research planning will lead to incorrect/ irrelevant and in turn to bad management decision.

The planning process

Every project must go through a planning process generally involving following steps.

- Recognition
- Design of alternative course of action
- Evaluate alternative course of action
- Selection of a course of action
- Modify and implement

The role of research in planning

At each step in the market planning process, research can help to give direction to the decisions that must be made. A continuous flow of research information is therefore needed to manage the process of decision making as indicated below:

Research for decision making

Decision making process	Research role/information needs
Set objectives Measure current performance Forest progress to objectives Identify gaps, reasons, priorities	Problem identification
Identify alternative solution Decide between alternatives Implement	Problem solution
Identify the results	Problem resolution

Planning the research design

In order to obtain research input a research design is necessary. This means deciding in advance what is required from research rather than finding out facts and making an interpretation which merely relies of professional judgement. Many research projects fail

because of inadequate preparation in developing the background of a study than because of insufficient technical knowledge. Put simply, the research design conveys the essence of a study.

Recognise and define problem

The key questions at the outset relate to objectives. Most research studies begin with a problem provoked by some practical or theoretical difficulty associated with attaining objectives.

A good starting point in understanding is to find out what happened before - to identify the history of the problem and *avoid reinventing the wheel.* The researcher and the marketing research must together define why the project is being undertaken. what the study is designed to measure and how the information will be used. In other words, how will such data reduce risk and help decision makers to make a more informed decision. The problem history and plan for information gathering.

- What does the researcher know about the situation?
- What assumptions are being used?
- Are the assumptions reasonable?
- If the assumptions turn out to be unrealistic how does this affect
- Is anyone on the research project team biased?
- How precise does the information need to be?
- Will precision affect the choice of an alternative?

One the problem has been defined, research is likely to be concerned with collecting informative data and other activities designed to solve the problem at hand.

Research design and project proposal

The identification of the problem will be followed by an appropriate design of the study. The design process culminates with a written project proposal that conveys the essence of the study. Statement 2 shows the steps involved in designing a market research project and questions to consider at each stage.

Problem definition	What decision and type of information will help?
Decide the value of information	What is the cost/risk/loss of opportunity in taking the wrong decisions?
Select data collection methods	What secondary, survey and experimentation methods and variations are needed?
Select measurement techniques	Which questionnaires, attitude scale, observation and /or productive techniques are required?
Select the sample	Which and how many respondents or things should be measured?
Select the analytical method	Depends on the sample and the questionnaire
Specify the time and the cost	Depends on the value of the information
Prepare the research proposal	
Evaluate and implement the proposal	

Statement 1. designing the research project steps

Case study on Akkelpur village

Akkelpur is a small tribal village. Along the north-eastern part of the village flows the Mohan river which acts as a natural boundary for the village. The village is surrounded by several plantations created by the Akkelpur villagers alone or jointly with the people from the neighbouring village on revenue wastelands and forest wastelands. Across the Mohan river, there is a patch of natural forests (the Garda forest) which is unprotected but an important source of fuelwood.

A Tatma tribe village, Akkelpur has 119 households with a total population of 581. The average family size is about 5. Since the entire village belongs to one tribe, most of the families are related and hence there is a strong unity amongst the families. Education is still not considered important by the villages. While majority of the men can read and write, very few women can do the same. In a single family, all the children are not sent to school, as grazing the animals and care for the younger sibling is an important task. As agriculture is primarily rainfed, women have to seek alternative employment sources, to supplement household income. Hence the older children become responsible for the household chores.

Table 1. Profile of village Akkelpur

Name of the village	Akkelpur
Number of households	119
Population	581
Caste/tribe	Tatma tribe
Geographical area (in hectares):	
Irrigated	4
Unirrigated	140
Revenue wasteland (afforested)	14
Gauchar	5.7
Livestock population	260
Anganwadi	Akkelpur
Primary school	Akkelpur
Middle school/College	Thawa (km)

Occupation

A survey conducted by a local organization in the village shows that only 4 families belong to the rich farmer category having more than 5 acres of land with irrigation facilities, electricity connection and a television set in the house and where atleast one member from the family has a steady government job. Another 41 households (34%) are landless for whom wage labour is the only source of income. However majority of the households (62%) belong to the small farmer category having less than 5 acres of land and for whom agricultural labour is an additional source of income.

Agricultural wage labour is the main source of livelihood for 30% of the families and secondary occupation for 74% of the households. The rest of the families have business or government service to support themselves. In many landless families, the men folk migrate from the village for 4 to 6 months in a year, mainly after harvesting the kharif crop (after Diwali). Migration to places as far as 100 km in search of agricultural wage labour is common among the men-folk. The women take up wage labour activities- agricultural or otherwise- in Akkelpur itself or in the neighbouring villages.

Livestock

The total livestock population of the village is 260 including buffaloes, bullocks, cows and calves. A few families have small numbers of goats too. The average cattle holding per family is about 2. However biogas-user families have a larger number of cattle (atleast 5) which ensures the availability of the dung required for the operation of the biogas plants. Grass collected from the private agricultural land, dry grass from the areas protected by the community and agricultural residue serve as fodder for the cattle. Groundnut residue, rice and wheat stalks are used as fodder for the animals. The village has 20 acres of *gauchar* land also where open grazing is practiced. The village has a Dairy Cooperative Society (DCS). All surplus milk, though in small quantities, is sold there at rates fixed by the DCS and varying according to the fat content.

Agriculture

The principal crops cultivated by the farmers of Akkelpur during the monsoon months, that is the Kharif crop are *dangar* (rice), *jowar* (Indian millet), *tuvar* (pigeon peas) and *urad*. *Sinh* (groundnut) and kapas (cotton) is grown as cash crops. During the Rabi season, wheat is cultivated primarily by the farmers having irrigation facilities. Only 5% of the families irrigate their land by using diesel pumpsets. Approximately 10 acres of the total land area in Akkelpur village is irrigated. Privately owned wells and the Mohan river

are the sources of irrigation water. There are about 9 wells situated in the agricultural fields of the farmers, most of which however remain unused due to the lack of access to lifting devices.

Drinking water

There are four wells and a handpump situated in different parts of the village and used by the villagers as drinking water sources. The average distance travelled to fetch water is not more than 0.5 km from the houses. There is no scarcity of water in the village.

Domestic energy use pattern

Majority of the households in the village use a mix of biofuels like wood, dungcake and crop residue for cooking and heating, every day. However fuelwood is the most popular fuel source in the village.

Saag, Kuhad, Khapra, Aal, Khir and *Subabool* are some of the popular tree species used as fuel. The relative ease in availability of wood and the fact that they are available at zero monetory cost, influences the dependence on biomass fuels and particularly wood for fulfilling the domestic energy requirements. Wood continues to be the most popular fuel source.

Wood is mostly collected from the forests by women and transported to the houses by headloads. In Akkelpur, in most households wood is gathered by the female members and in many cases 2 to 3 of them go at a time from one household. Wood is collected in winter which is a lean period for agricultural activities. Some women gather wood in the summer months whenever free time is available. The forest plantations developed within the JFM program seems to be the primary source of wood for 72% of the families, while 17% of the families collect wood from their own agricultural fields or from the roadside. Another 11% of the families use the degraded Garda forest across the Mohan river. The average distance of these forest areas from Akkelpur is 2 to 3 km.

Dung cakes are prepared and stored in winter months for usage during the summer and monsoons. In winter the dung availability increases because of a steady supply of good fodder. Crop residue from the harvested Kharif crops and dry grass from the community plantations is available during the winter months in plenty. Some of this is stored for consumption over the rest of the year. In most households 40% of the collectible dung is used to prepare dung cakes. In households without cattle (which is about 17% of the total households in the village), dungcakes are prepared out of the dung collected from the common areas of the village like the road, near the river and the pasture land.

Tuvar is the most common crop residue utilized as fuel. Tuvar is harvested in April-May and therefore used through the summer and monsoons. Small quantities of the material are used daily, primarily for igniting the fire. Tuvar stalks and dung cakes are stored in dry places inside the house and hence are used more frequently in the monsoon. In a few large farmer households, cotton residue is also utilized as fuel. The seasonality of fuel usage reflects the following pattern:

Summer	**Small amounts of crop residue, wood & dungcakes**	**5 months**
Monsoon	**dungcakes & crop residue & wood**	**3 months**
Winter	**primarily wood & dungcakes**	**4 months**

There are two large farmer households, whose energy consumption pattern differs from the general pattern in the village. In one household. kerosene is used for all cooking and heating purposes. The family purchases 20-25 litres of kerosene per month for an adult population of 3. In another household 17 adult cattle heads are available producing about 180 kg of animal dung per day. This family has a biogas plant. but there is enough surplus for preparing dungcakes as well. Hence 12 kg of dungcake is the average daily fuel consumption.

Lighting

35% of the houses in the village are electrified. However electricity supply is very erratic, especially in the monsoons. Each household have two light points (each of 60 W). The supply during the monsoons is for nearly 2 hours per day. while during the winters and summers, it is for nearly 6-8 hours per day. Kerosene continues to be the primary source of lighting in majority of the households. Approximately 5 litres of kerosene is required per month for lighting purposes. Apart from one pucca house in the village. all houses are made of dung, black soil and bamboo. Repairs once a year preferably before the monsoon is essential in all these houses. A month before the onset of monsoons. the dung required for this purpose is collected and stored.

Biogas programme in Akkelpur

As a continuation of the implementation of biogas programme in the villages of Valia Taluka of Sonagarh, biogas plants were installed in Akkelpur also in 1993. The villagers of Akkelpur also participated in several forest protection efforts with the neighbouring Pingot village and also in its own village. This enthused them to undertake further forest conservation measures and biogas plants seemed to be a feasible option. The success of the

technology in the neighboring villages and its perceived usefulness, prompted the Akkelpur VMS (Village Management Society) to initiate the programme in the village too.

The biogas programme in Akkelpur was initiated in May 1993. PRA study was done to identify the potential households where biogas plants could be installed on the basis of the livestock size, water and space availability. The exercise showed that space was adequately available as *Vara* land (kitchen garden) in all households. Water was available within a distance of 0.5 km from the house. In terms of cattleheads, the households could be divided as follows.

Table 2. Cattle holding per family

Cattle holding	No. of households
0	20
1-3	60
4-8	40
More than 8	5

Hence from the above survey 37 families had resources to install biogas plants of 2 cum. size, while 3 families could have 3 cum size of biogas plants installed in their houses. 79 families indicated zero potential for biogas plants. Accordingly in May-June 1993, 22 biogas plants were installed in the village.

Table 3. Total number of biogas plants installed in village Akkelpur

Catagory of households	Plant capacity		Total number of plants
	2 cum	3 cum	
Large farmer	2	2	4
Small farmer	10	1	11
Landless	6	1	7
Total	18	4	22

In May 1988, a biogas plant of 3 cum size had also been installed by State nodal agency. However, this plant has been un-functional for almost 5 years now. In line with the Voluntary Forum's policy to appoint women motivators to promote the program amongst women, Akkelpur VMS (Village Management Society) appointed a woman Field Volunteer (FV). The biogas plants in the village were constructed by masons from neighbouring village. There is only one mason in Akkelpur village.

The cost of construction of biogas plants is reduced by the subsidy offered by the Ministry of Non-Conventional Energy Sources. Hence the total amount of subsidy works

out to Rs. 4,200 for a 2 cum plant and Rs. 4,700 for a 3 cum biogas plant. The user's contribution included Rs.425 in cash as payment for the mason and FV along with the responsibility for digging the pit.

Status of the biogas plants

Out of the total number of 23 biogas plants (including the one installed by State nodal agency) in the village, 9 were totally defunct at the time of the survey (October 1995) indicating a functionality rate of 61% for the biogas programme, where the inefficiently working plants have been taken into account as working.

Table 4. Present status of Biogas Plants installed by Voluntary Forum in 1993

Plant Size	Category of household as per land holding						Total	
	Large farmer		Small farmer		Landless			
	Installed	Unfunctional	Installed	Unfunctional	Installed	Unfunctional		
2 cum.	2	2	10	3	6	2	18	7
3 cum.	2	0	1	1	1	0	4	1
TOTAL	4	2	11	4	7	2	22	8

For the unfunctional plants, reasons for unfunctionality were examined. Pipeline leakage near the dome valve and broken pipelines account for 44.5% each of the plants lying unfunctional. 11 % of the plants are unfuctional due to dome leakages. Here technical snags and the consequent lack of repairs is responsible for biogas plants being out of working conditions, since pipeline leakages and damages are easily repairable.

In addition to the plants which are completely out of order, there are 8 more plants (36% of the total plants installed) which are inefficient, that is, working below full potential. The reasons for unsatisfactory working of plants are listed below:

Table 5. Reasons for defect in the plant

Nature of defect	No of plants with the defect
Pipeline damage	1 (12.5%)
Pipeline valve leakage	6 (75%)
Damper damage	3 (37.5%)
Stirrer damage	2 (25%)
Water trap damage	1 (12.5%)
Stove knobs broken	1 (12.5%)

It can be seen from the table that 75% of the inefficiently working plants are suffering from pipeline leakage near the delivery valve. An analysis was also carried out of the duration for which plants have remained unfunctional. All the 9 plants which have been unfunctional. have been out of order for an average period of 17 months. On the other hand 8 months is the average time period over which some of the biogas plants have been working inefficiently. Given below is distribution of plants not working over different ranges of time.

Table 6. Time duration for which biogas plants have remained unfunctional/inefficient

Time period (months)	Unfunctional plants	Inefficient plants
0.5-6	4	4
7-12	1	3
13-18	1	1
19-24	1	
More than 24	2	

An analysis of the size of biogas plants constructed in Akkelpur, reflects a predominance of 2 m^3 size of plants. This is because the average cattle holding size per family is 5 which would provide the necessary dung for 2 m^3 size biogas plants. The average collectible dung per day per biogas-user household works out to be 41 kg which is about 20% less than the required 50 kg of fresh dung per day for a 2 m^3 plant. Experiments in Akkelpur showed that gas production is lower than planned. Studies show that 1 kg of fresh dung should produce 0.04 m^3 of biogas. For the 2 m^3 plant studied in Akkelpur. 48 kg of fresh dung feeding yielded 0.67 m^3 gas per day, which is 66% less than the expected output of biogas. This indicates that

(a) biogas plants are underfed, and
(b) the gas production per kg of dung input is lower than expected, i.e. the plants are working below full potential.

In the monsoon months, all plants function much below the potential. since the animal dung is utilized as organic manure in the agricultural fields. On the other hand. efficiency of plants improve during winter, as adequate fodder is available to the animals which thereby increases dung production.

Present energy consumption pattern

The following table summarises the present energy consumption pattern in the village, both in the biogas user and non-user household.

Table 7. Present energy consumption pattern (Per capita per day)

Fuel-type used	Biogas user (Average values)	Non-user (Average values)
	14 households	105 households
Fuelwood (Kg)	0.75	1.80
Dungcake (Kg)	0.40	0 50
Crop residue	0.20	0.10
Biogas (cu. m)	0.06	..

What you need to do

- Develop a questionnaire for collecting information from the households on - demographic , energy consumption pattern, development priorities
- Estimate the total energy consumption pattern in the village.
- Suggest a strategy for rectification of both unfunctional and inefficient biogas plants and develop an efficient management system for the repair and maintenance of these plants.
- Using the data available, suggest an intervention of other technologies to meet the lighting and cooking requirements of the village